EDN®

THE DESIGN MAGAZINE OF THE ELECTRONICS INDUSTRY

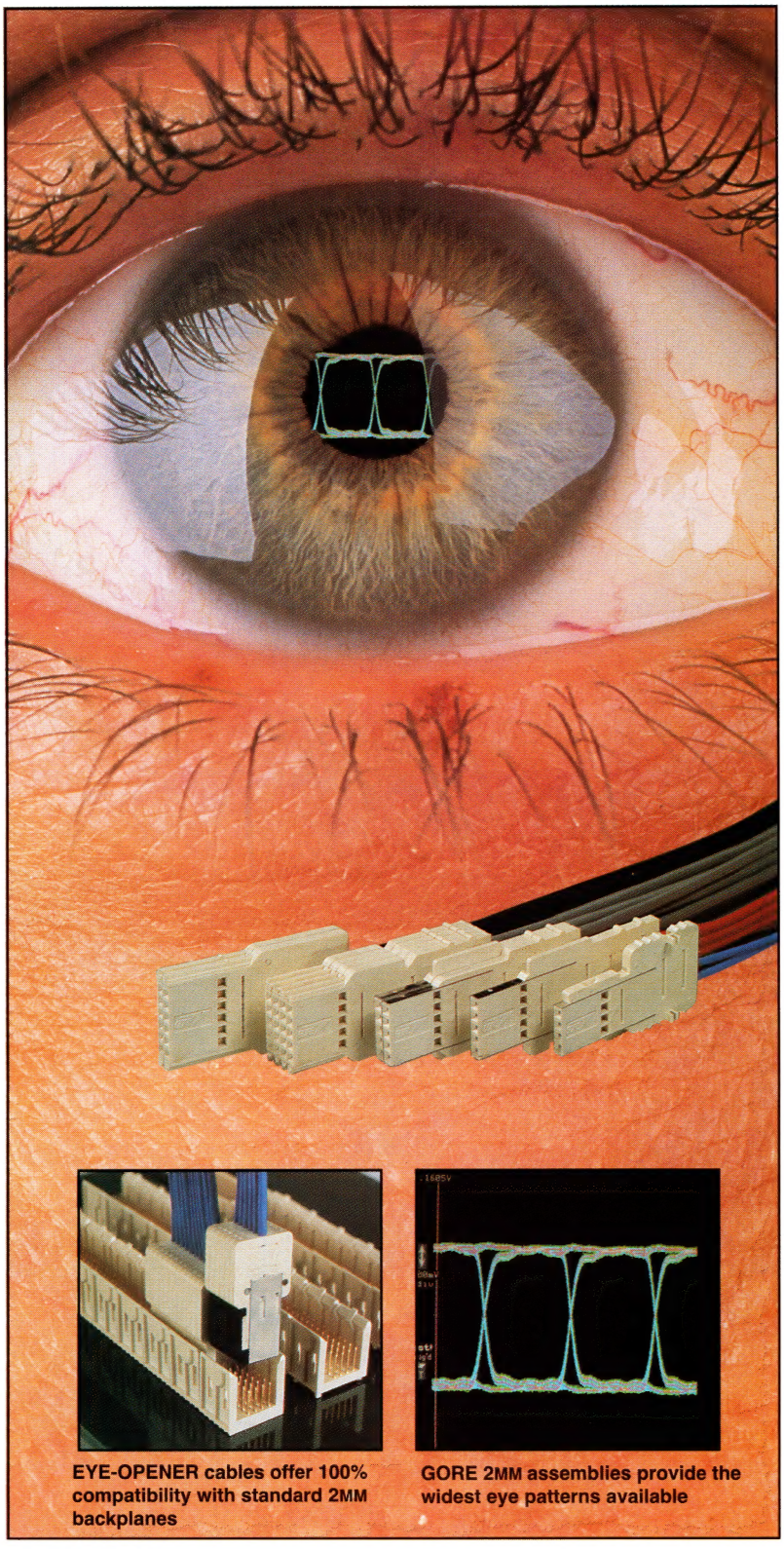
DECEMBER 22, 1994

HOT TECHNOLOGIES COOL APPLICATIONS

A CAHNERS PUBLICATION

Gore's New 2MM Cables -

An Eyeful of Fidelity and Reliability



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CIRCLE NO. 1

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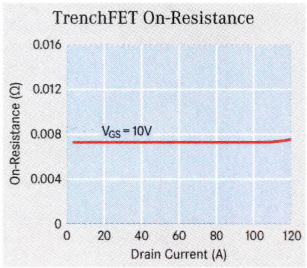
Introducing Siliconix's new TrenchFET™ power MOSFETs. Low on-resistance dramatically reduces parts count and increases board reliability.



Thanks to a new process developed and patented by Siliconix, our new family of TrenchFETs feature 8 million cells per square inch and deliver on-resistance as low as 8mΩ with a 60-V breakdown voltage and 175°C maximum junction temperature. The result is fewer parts and smaller, more reliable board designs for automotive applications such as airbags, ABS, power steering, window lifts, motors and fuel pumps.

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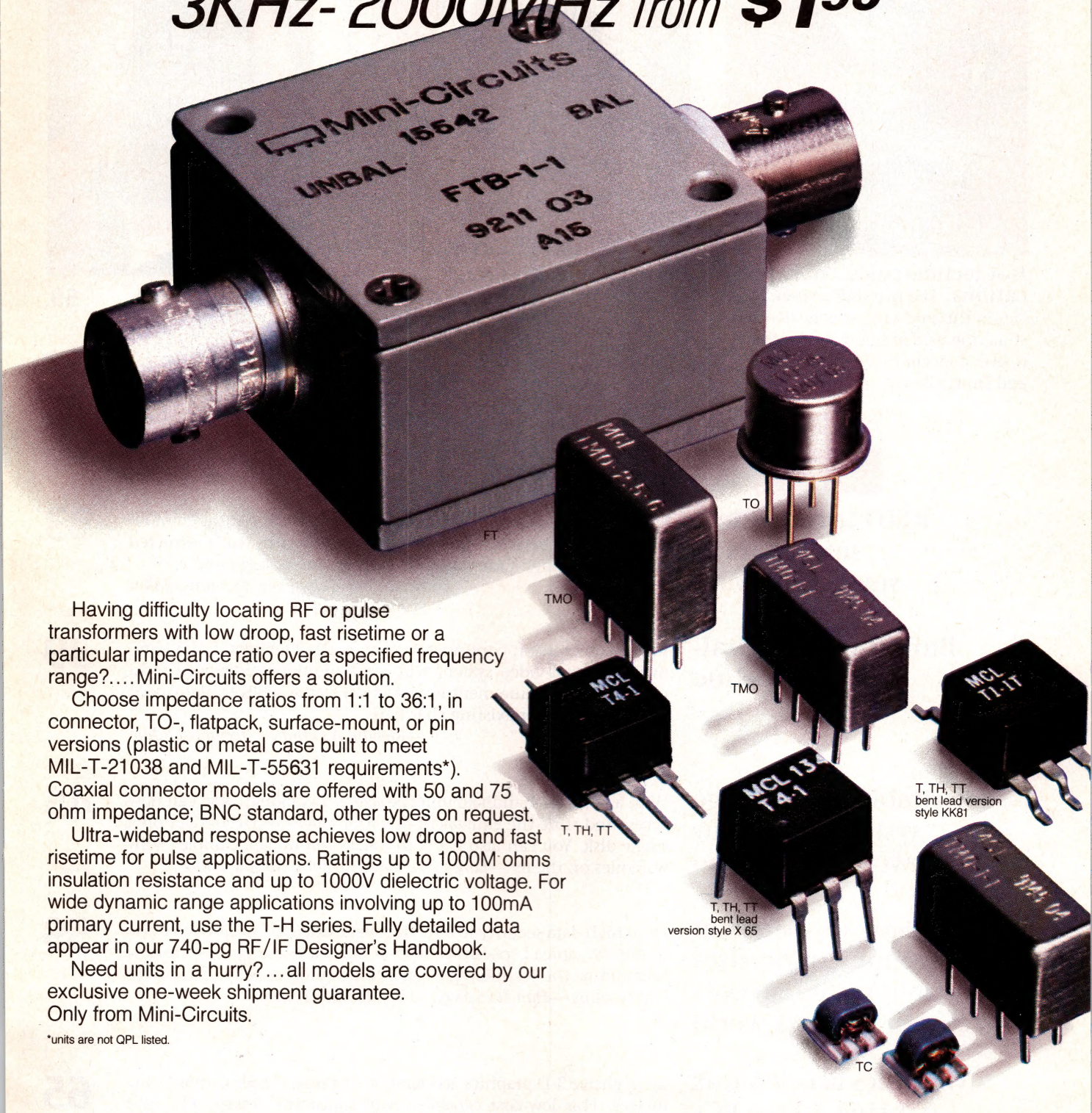

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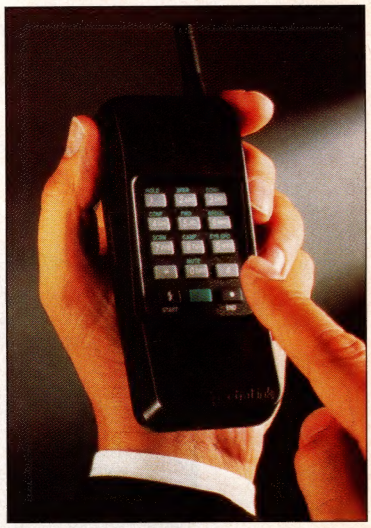
CIRCLE NO. 69

F 71 Rev F

EDN DECEMBER 22, 1994 A Cahners Publication/Volume 39, Number 26

Hot technologies, cool applications: The five staff-written articles in this end-of-year issue demonstrate the uses of hot technologies. (Cover concept by Chinsoo Chung and Doug Glen)

Rewritable data-storage system 45

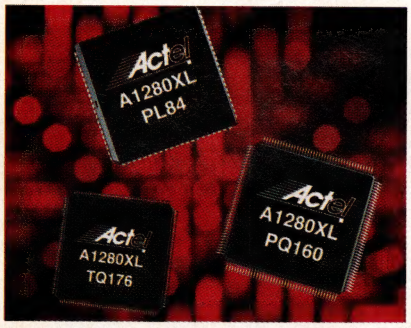


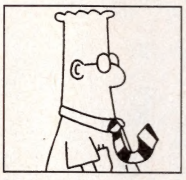
Spread-spectrum technology 59

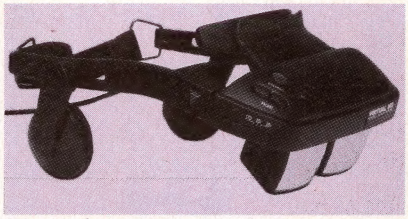
EDN

DESIGN FEATURES

OUT IN FRONT







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EDN | PRODUCTS

EDN | DEPARTMENTS

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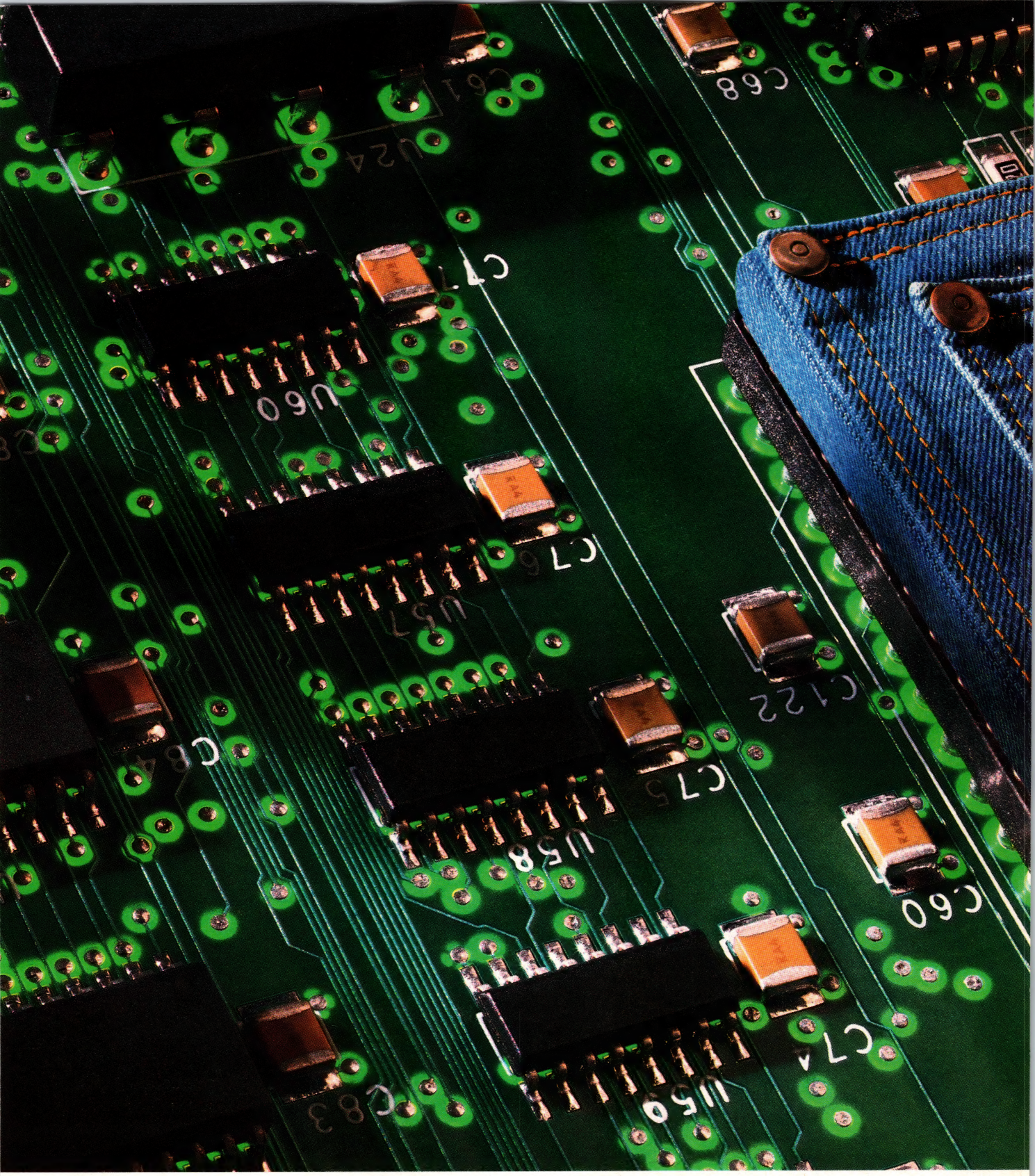
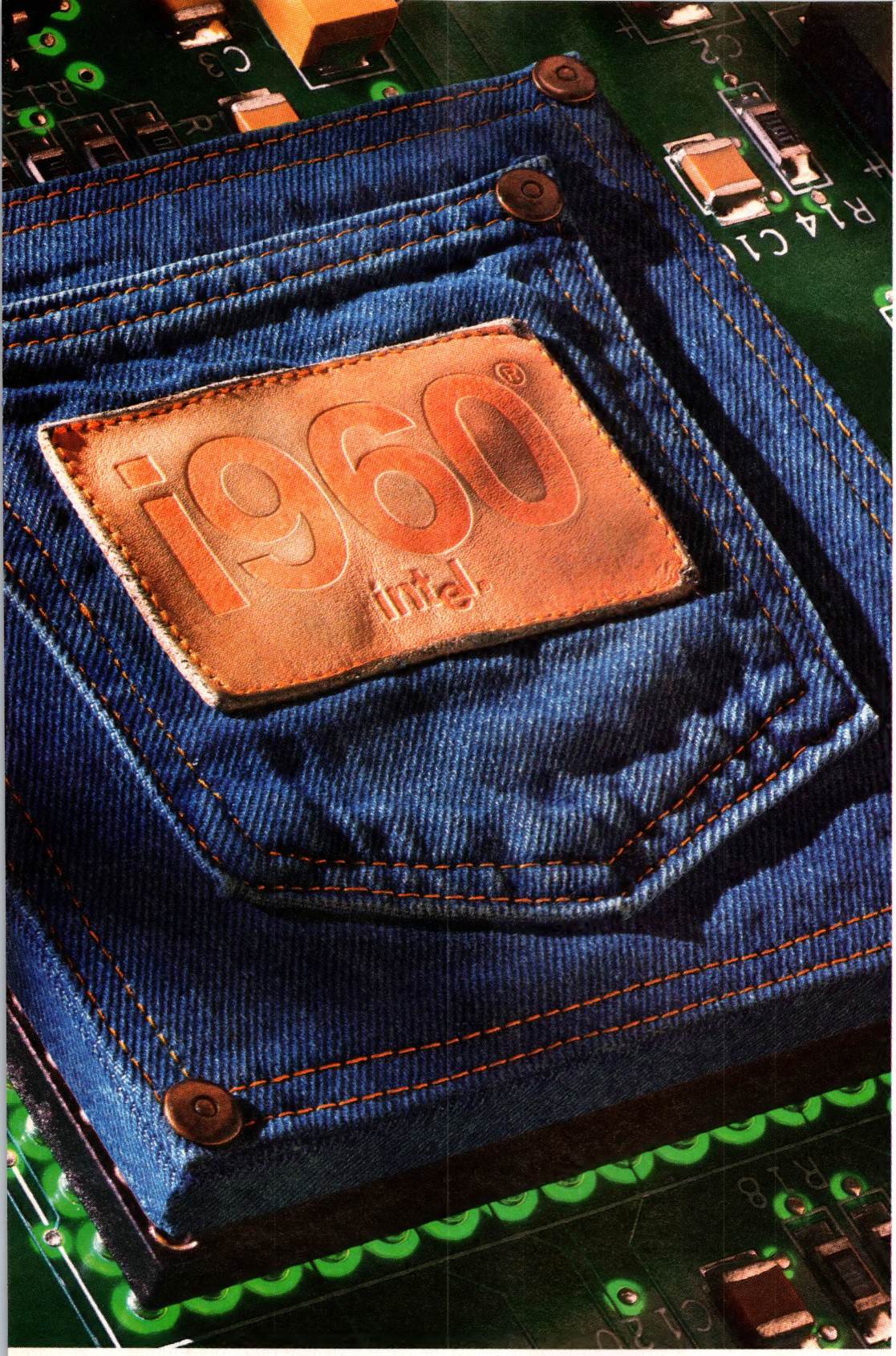
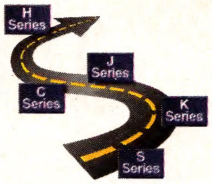


Choose an embedded processor





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CIRCLE NO. 49

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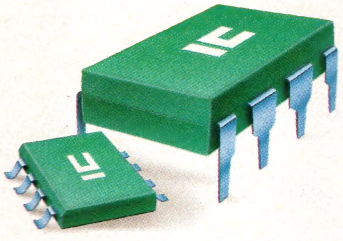

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CIRCLE NO. 79

FPGA family goes head-to-head against masked gate arrays

The A1280XL family of FPGAs comes in three varieties that challenge the position of low-end masked gate arrays.

The 1200XL family of field-programmable gate arrays (FPGAs) from Actel brings antifuse technology to designers using traditional low-end masked gate arrays. The three parts, which are available in two speeds, range from 2500 to 8000 gates. Taking advantage of 0.65-μm design rules and redesigned I/O modules and clock-distribution networks, the products offer system performance as fast as 60 MHz and a maximum flip-flop frequency of 135 MHz.

The A1225A has a 24-nsec clock-to-output time, and the A1225XL-1 has a 10-nsec clock-to-output time. These speeds let you build 40-MHz DMA controllers, 33-MHz Ethernet controllers, and 75-MHz disk controllers. All three devices in the family come in 84-pin PLCCs. The 2500-gate, 83-I/O A1225XL also comes in a 1-mm-high, 100-pin VQFP, which meets the design requirements for PCMCIA Type I, II, and III cards. Both the 4000-gate, 104-I/O A1240XL and 8000-gate, 140-I/O A1280XL offer 176-pin TQFP options. The three XL parts are also available in PQFPs.

The A1280XL and A1280XL-1 are immediately available. Quantity prices for the A1280XL are $46.20 in an 84-pin PLCC and $52.50 in a 160-pin PQFP. The A1240XL, A1240XL-1, A1225XL, and A1225XL-1 will be available in the first quarter of 1995.—by John Gallant

Actel Corp, Sunnyvale, CA, (408) 739-1010.

Circle No. 400

Support blossoms for Power PC

IBM Corp is now offering development tools for the PowerPC. The tools, which are available to qualified third-party developers, include both board- and system-level reference designs. The boards' prices average $2500, and the systems' prices average $5000. Further, the company has opened a technical-support center in Austin, TX, that assists developers with product and technical inquiries.

With Hewlett-Packard and Logic Modeling Inc, IBM is also offering architectural-simulation software, logic analyzers, and debuggers. The company is providing compilers, linkers, and runtime libraries to qualified developers; interested parties must contact an IBM manufacturer's representative for price and qualification criteria.

—by Richard A Quinnell

IBM Microelectronics, Hopewell Junction, NY, (800) 769-3772.

Circle No. 401

Free Spice newsletter discusses connector modeling

The free *Intusoft Newsletter* discusses the Spice circuit-simulation program. The latest issue contains several application notes to help engineers more effectively simulate circuits. For example, one article discusses connector modeling and provides examples of how designers can model connectors using 3-D electromagnetic field-solver programs and Spice. As an example, the article discusses modeling a D-type connector with Ansoft's Maxwell 3-D field simulator and then simulating the connector with Intusoft's IsSpice.

In the past, engineers could model a connector as a simple dc resistance because pc-board sign speeds were slow. But in today's high-speed RF and microwave environments, engineers cannot always use this technique because designers must account for connector effects. Using the Spice subcircuit for a connector, designers can simulate various situations, including bandwidth, transit-time delay, reflections, and crosstalk.

A floppy disk containing the schematics and Spice models in the newsletter, several connector models, 18 models for Maxim's low-power op amps, and 12 models for Burr-Brown devices is available for a nominal fee. A yearly subscription service, which includes a floppy disk with each newsletter, is also available.—by Fran Granville

Intusoft, San Pedro, CA, (310) 833-0710.

Circle No. 402

ISSCC '95 presents benchmark papers, adds tutorials

The benchmark papers emerging from the 1995 International Solid State Circuits Conference (ISSCC) (Feb 15 to 17, 1995, at the San Francisco Marriott) will discuss the advancement to "giga" levels of performance in many areas. Those areas include memories (1-Gbit DRAMs), μPs (giga instructions/cycle), communications (gigabit/sec circuits), and analog design (gigabit/sec and gigasample/sec circuits). The number of papers that establish these new benchmarks far exceeds that of previous years' conferences, according to Tim Treadwell, ISSCC program chairman.

The conference theme is "The Digital Highway," and two plenary talks support this theme: "Digital Storage Media in the Digital Highway Era" by Toshiyuki Yamada of Sony Corp and "Gigachip Vehicles Driving the Digital Information Highway for Work or Play" by Pallab Chatterjee of Texas Instruments. Raymond DuPont of the IBM/Motorola/Apple collaboration presents a third plenary talk, "The Making of the PowerPC."

One significant change for '95 is the addition of six 90-minute tutorials to take place on the Tuesday before the conference. The topics and expert instructors include: oversampling data conversion by Richard Hester, a fellow at Texas Instruments; clocking for high-performance systems by Mark Horowitz, an associate professor at Stanford University; RF communications systems and circuits by William Ooms, a research manager at Motorola; cache memory by Roy Flaker, senior technical staff member at IBM; image sensors by David Barbe, a professor at the University of Maryland, and Charles Stancampiano, a device engineer at Eastman Kodak; and high-disk-drive signal processing by Richard Yamasaki, a corporate fellow at Silicon Systems. Although not firm yet, the price of these tutorials will be around $45, with a discount likely for those attending more than one.

Other changes include an increased number of Friday-afternoon sessions. The topic of the short course on the Saturday following the conference is wideband digital data communications; that session will emphasize asynchronous transfer mode. Two sessions will accommodate approximately 150 people each. Attendance is limited; this course has sold out in advance for the last two years.

Evening panel-discussion topics include: "Analog BiCMOS: Luxury or Necessity?"; "In-House CAD vs Vendor CAD for High-Performance VLSI"; "Monolithic Surface-Micromachined Sensors: IC Technology of the Next Century?"; and Radio Front-End and Digital Signal Processing: Are the Technologies Incompatible or Just the People?"

—by Anne Watson Swager

ISSCC Conference, Washington, DC, (202) 639-4255.

Circle No. 403

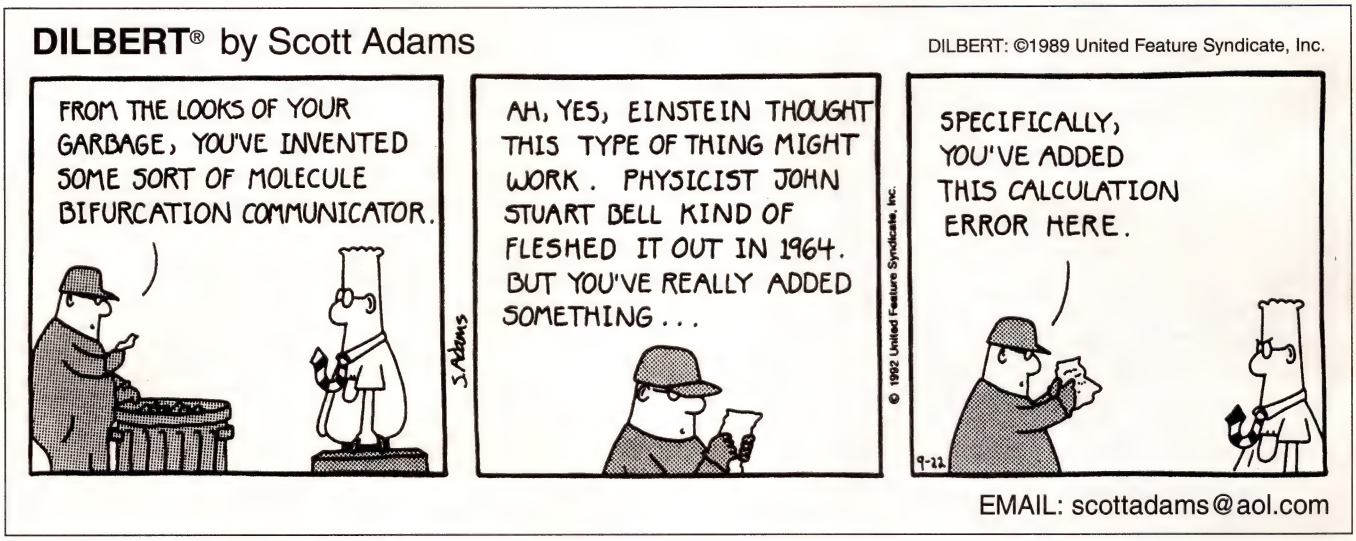
Visual Basic state-machine tool simulates user interfaces

A Visual Basic-based diagrammatic state-machine-design tool, BetterState for Visual Basic (BS4VB), lets you design state machines on your PC screen and simulate how the machines react to inputs from Visual Basic controls. The result is a visual prototype that reacts much as a real product would to button pushes, timers, and other events that you create or simulate with Visual Basic. You can obtain BS4VB as a $295 stand-alone product or as a part of the vendor's $495 BetterState Pro graphical-entry and code-generation package, which generates C, C++, Verilog, and VHDL code.

BS4VB includes Interactive State Animation, which animates the state diagram to reflect program execution. The tool also includes Animated Playback, which uses VCR-like forward, reverse, and pause controls to allow you to review state transitions that were executed and recorded during a simulation. Another feature, Interactive State Traveler, animates compound state transitions without running a debug, simulation, or playback session, allowing you to visualize complex transitions in a language-independent way.—by Dan Strassberg

***R-Active Concepts Inc**, Cupertino, CA, (408) 252-2808.*

Circle No. 404



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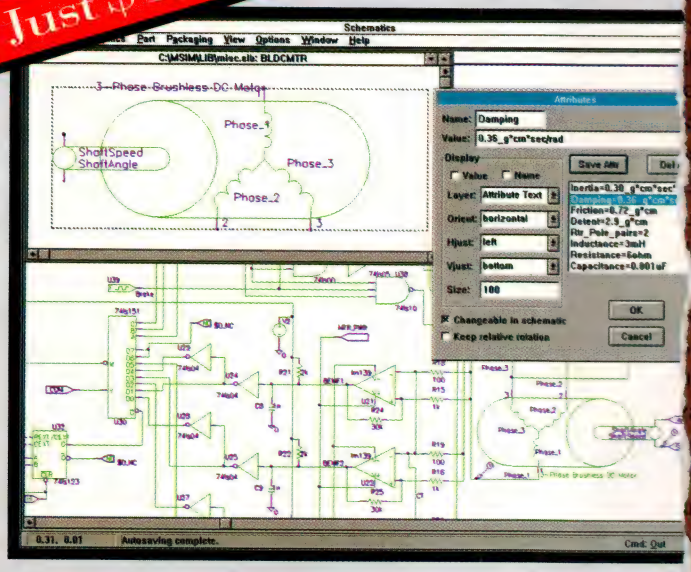

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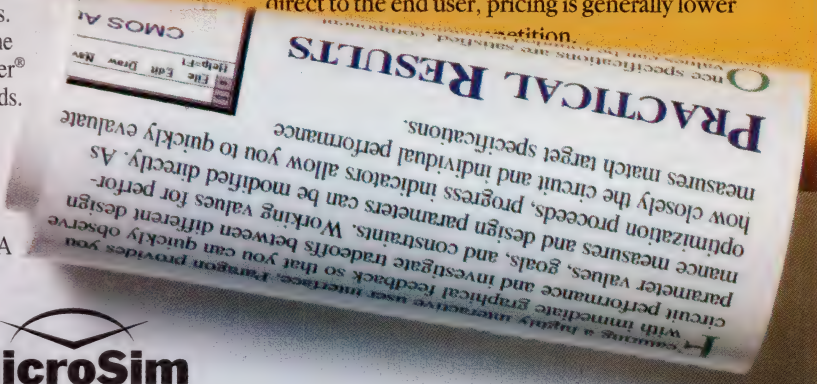
products in the MicroSim Design Center. Schematics is tightly integrated with products for: analog, digital and mixed A/D simulation; programmable logic synthesis, signal integrity analysis, analog performance optimization, filter design and more.

MicroSim Schematics for Windows

The Schematics product from MicroSim combines a richer feature set than most schematic packages, with an ease of use that busy designers seem to appreciate. A short list of outstanding features includes:

- *Easy-to-use interface.* The standard Windows user interface allows editing tasks to be accomplished with a minimum of menu commands. The multi-window interface allows viewing and editing of different pages or different levels of a hierarchical design at the same time.
- *Fast 32-bit performance.* Schematics offers faster netlisting, schematics loading, symbol loading and faster graphics.
- *Support for both flat and hierarchical designs.* Creating a hierarchical block is as easy as placing a block and double-clicking to push into the sub-schematic it represents. Schematics can also automatically create a symbol for a sub-schematic so that it can be easily reused.
- *Integrated symbol editor.* Schematics allows the user to view, modify, or create symbols while editing the schematic – and it comes with a large library of symbols for over 28,000 parts already defined.
- *Interfaces to external board layout packages.* Schematics can produce a CADSTAR, PADS, P-CAD, Protel, SCICARDS, Tango or EDIF 2 0 0 layout netlist from a completed circuit drawing due to integrated interfaces. It also includes backward ECO support.

With this impressive list of features, it seems the MicroSim Schematics product would be costlier than most. A comparison shows the opposite to be true. Because MicroSim sells direct to the end user, pricing is generally lower



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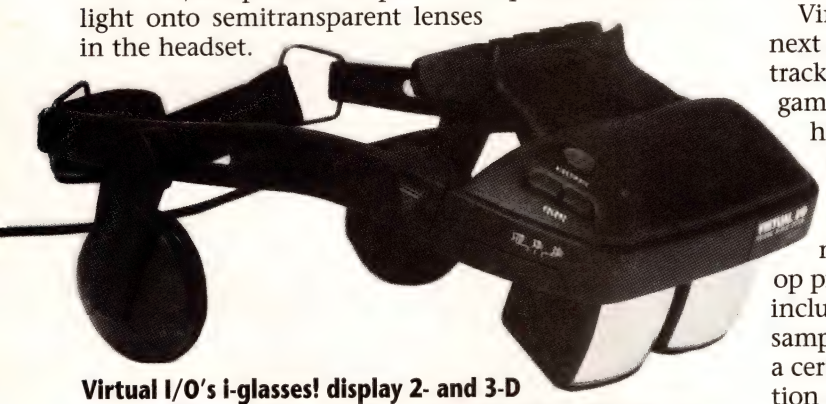
HEADSET PROVIDES REALISTIC 3-D IMAGES

A new personal display system (PDS) from Virtual I/O allows users to view full-color video images and the peripheral environment simultaneously. This technique means that users are less likely to experience motion sickness or vertigo than when using conventional head-mounted devices, according to the company. The i-glasses! system displays 2- and 3-D movies, TV programs, and PC and video games in color with stereo sound and visuals. In addition, users can see through the device when it is turned off, and it does not obstruct peripheral and downward vision when in use.

The 7-oz device projects light through two 0.7-in. LCDs with 138,000 pixels/LCD panel. The product focuses the light onto semitransparent lenses in the headset.



Virtual I/O's i-glasses! display 2- and 3-D movies, TV, and PC and video games in color with stereo sound and visuals.

This technique provides a head-up, 30° diagonal field of view and an image that the user perceives as an 80-in. TV screen at an 11-ft viewing distance. The device's audio features include 22-Hz to 20-kHz frequency response and a 1/8-in., 1V p-p stereo.

Display uses of i-glasses! include video entertainment, multimedia, PC and electronic games, 3-D viewing, virtual reality, TV, industrial, and test-and-measurement applications. The device accepts standard video from cable TVs, broadcast TVs, VCRs, laser disks, and electronic games; it also accepts NTSC-converted VGA data. List price will be $599. An optional PC module provides head tracking and a VGA converter for $200.

Virtual I/O also plans to unveil two more PDS products next year. The Gamer!, an 11-oz PDS, uses real-time head tracking to create a 360° environment for all major video-game systems. Price will be $399. The UltraView 2020, a high-end color VGA system, suits industrial, military, and professional applications. Virtual I/O individually customizes and prices each UltraView 2020.

Through a corporate-partners program, companies can use Virtual I/O's display technology to develop products. The program offers a $1500 developers' kit, including i-glasses!, 3-D and head-tracking specifications, sample software routines, resources for technical support, a certificate for future product discounts, and an instruction manual.—by Fran Granville

Virtual I/O, Seattle, WA, (206) 382-7410.

Circle No. 405

Extension doubles SCSI data rate

DoubleSpeed SCSI (also known as Ultra SCSI) doubles the maximum parallel SCSI I/O data rate to 40 Mbytes/sec. Because this extension uses the same cables, connectors, and software as SCSI, it lets manufacturers provide a low-cost upgrade path with low risk to existing configurations.

DoubleSpeed/Ultra SCSI closes the gap between systems, such as the Pentium PC, using the Peripheral Component Interconnect (PCI) bus and computer peripherals. The extension thus maximizes PCI's 133-Mbyte/sec data rate, according to Adaptec, one of a group of manufacturers that has announced support for DoubleSpeed/Ultra SCSI. Among the other companies supporting the extension are AT&T Global Information Solutions, Dayton, OH, (513) 445-5000; Ciprico Inc, Plymouth, MN, (612) 551-4000; Conner Peripherals Inc, San Jose, CA, (408) 456-4500; Hewlett-Packard Co, Santa Clara, CA, (408) 553-6813; Intel Corp, Hillsboro, OR, (503) 696-8080; Quantum Corp, Milpitas, CA, (408) 894-5090; and Seagate Technology, Scotts Valley, CA, (408) 438-6550.

—by Fran Granville

Adaptec, Milpitas, CA, (408) 945-8600.

Circle No. 406

Chip set provides CDPD and V.32bis modem coverage

The RC32ACC cellular digital packet data (CDPD) and V.32bis modem chip set from Rockwell Telecommunications provides the control link of a CDPD system. CDPD provides a secure and reliable digital data link for wireless communications. The technology sends packets of data as fast as 19.2 kbps during the gaps between normal voice calls.

CDPD provides connectionless service with automatic roaming and hand-offs, ensuring that no calls are dropped. Encrypted transmission provides additional data protection. CDPD also uses the Internet Protocol to send messages across the network, which guarantees the availability of a wide range of compatible software.

The RC32ACC also provides V.32bis data and V.17 fax dial-up capability. Users can employ cellular-switch cellular in areas lacking CDPD coverage. The RC32ACC is pin-compatible with the company's RC144ACL data/fax modem, allowing users to upgrade. The RC32ACC comes in two PLCC packages or a low-profile, three-device PQFP for $60 (10,000).—by John Gallant

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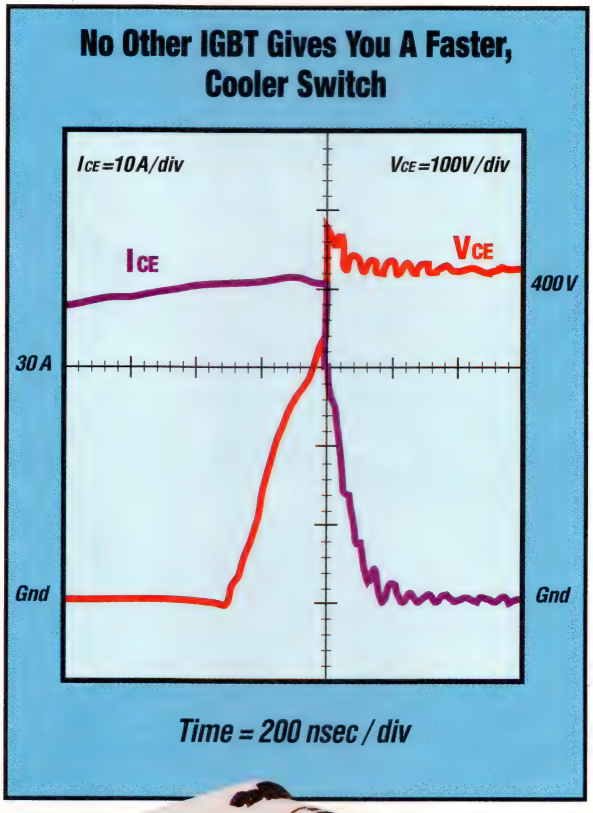

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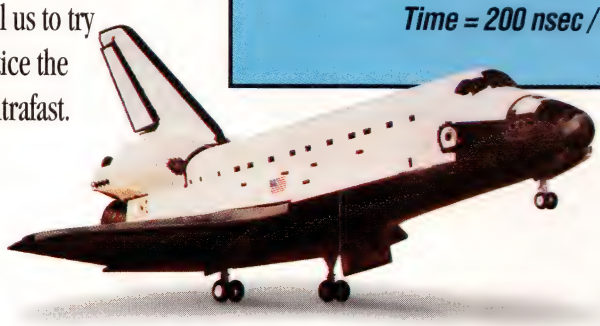

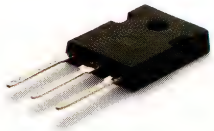

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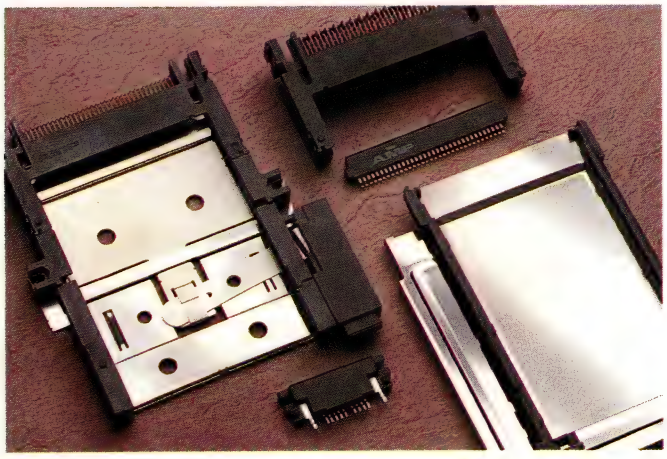

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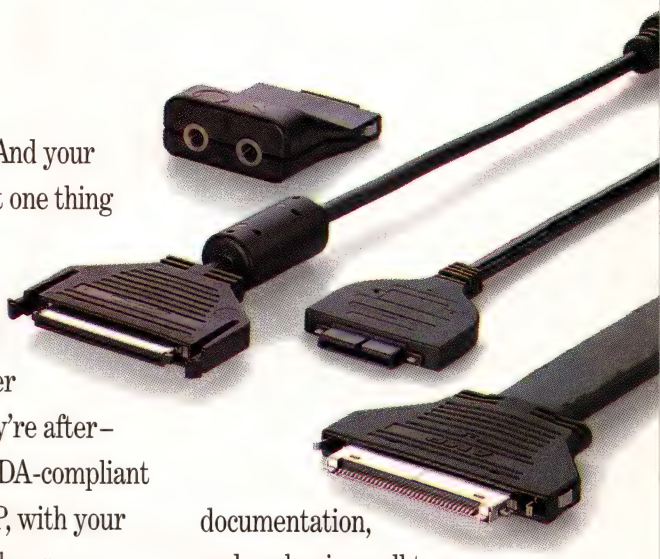

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Hot technologies at Comdex Fall '95

Welcome to *EDN's* annual "Hot Technologies of the Year" issue. We think the end of the year is a good time to step back and take a look at how designers are applying some of the industry's hottest technologies. As I write this, I've just returned from Comdex Fall '95, and I've seen some truly hot technologies that you should consider using—even if you're not designing PCs.

For example, CD-recordable (CD-R) disk drives, formerly priced at $5000 and up, are getting far less expensive. I met with two companies planning to push the cost down aggressively. Ricoh (San Jose, CA) showed me its $2495 RS-1060C double-speed CD-R external SCSI drive that will ship in February. Later in 1995, the company plans to introduce a lower cost, double-speed CD-R drive that can read CDs at quad speed. The target OEM price for this drive is around $700! Plasmon Data (Milpitas, CA) also showed me its lower cost, double-speed CD-R drive: the RF4100. Plasmon is bundling in Corel's CD Creator mastering software. CD-R media cost between $10 and $20 per disk.

These lower cost CD-R drives have obvious applications in the PC and workstation markets, but you might consider using this technology for other applications, too. With the cost of CD read-only drives now starting at less than $100, you could put 650 Mbytes of information into your system at a very low cost. Further, the advent of reasonably priced CD-R drives and media allows you to use CD-based storage cost effectively, even at low volumes. Recordable CDs let you avoid the NRE charge for CD-ROM mastering.

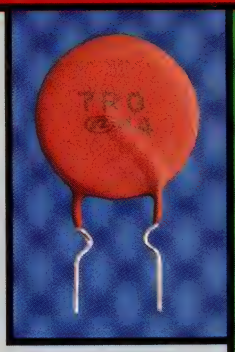
Similarly, both Duracel (Bethel, CT) and Energizer Power Systems (Gainesville, FL) have been working furiously to help you avoid delving into the mysteries of battery chemistry. These companies have integrated silicon into smart battery packs. The smart packs can communicate with charging and battery-monitoring systems to control charge and discharge rates. They report battery capacity and state of charge and track the number of charge/discharge cycles the battery endures. The packs also monitor their capacity degradation over time to alert the system when a new pack is required. You don't have to be a PC designer to take advantage of smart batteries; you just need to be smart about leveraging the high-volume technology created for the PC market.

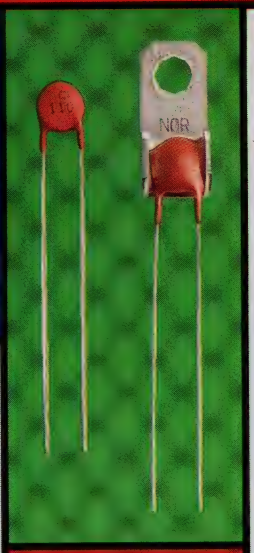
Finally, I'd like to tell you about a hot technology that's a bit off the beaten path for *EDN*. It's a product called Grip-it Strips from Better Hold Products (Menlo Park, CA). These strips solve a problem that's bothered me ever since I started packing a laptop computer. I've always feared the day when my PC slips from my fingers and crashes to the floor. Grip-it Strips are made from the same sort of self-adhesive plastic used to make nonslip stair-tread and bathtub appliqués. The company die-cuts the plastic into strips that you stick on PCs and other portable electronic gear. This product is one of those obvious things—after you see it.

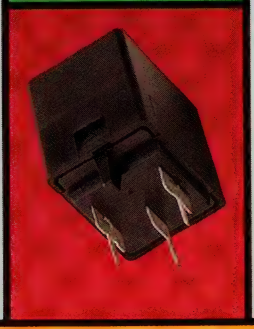
Steven H. Leibson

EDITOR IN CHIEF

Send me your comments via fax at (617) 558-4470, or on the EDN Bulletin Board System at (617) 558-4241, 300/1200/2400 8,N,1. From the Main System Menu, enter ss/soapbox and select W to write us a letter.







If you could afford it, you'd protect every circuit with a self-correcting system. A system that stops an overvoltage instantly — and then comes back on-line automatically after the overvoltage is gone. That's what you get with a Nichicon "Posi-R™" positive thermistor. And you get it at a price that compares with components you have to take out and replace every time there's an overload. There are six different thermistors in the Nichicon line. Every one of them can give your product this incredible ability to repair itself. Now that you can afford it, how can you possibly do without it?

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Nichicon "Posi-R™" positive thermistors. For overcurrent protection, thermal protection and automatic color TV degaussing. Call for a catalog: 708/843-7500.

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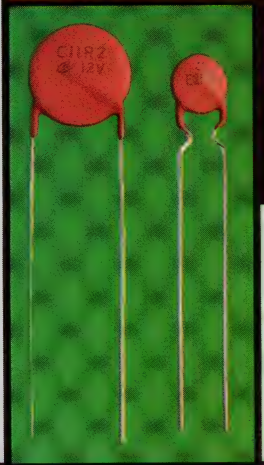
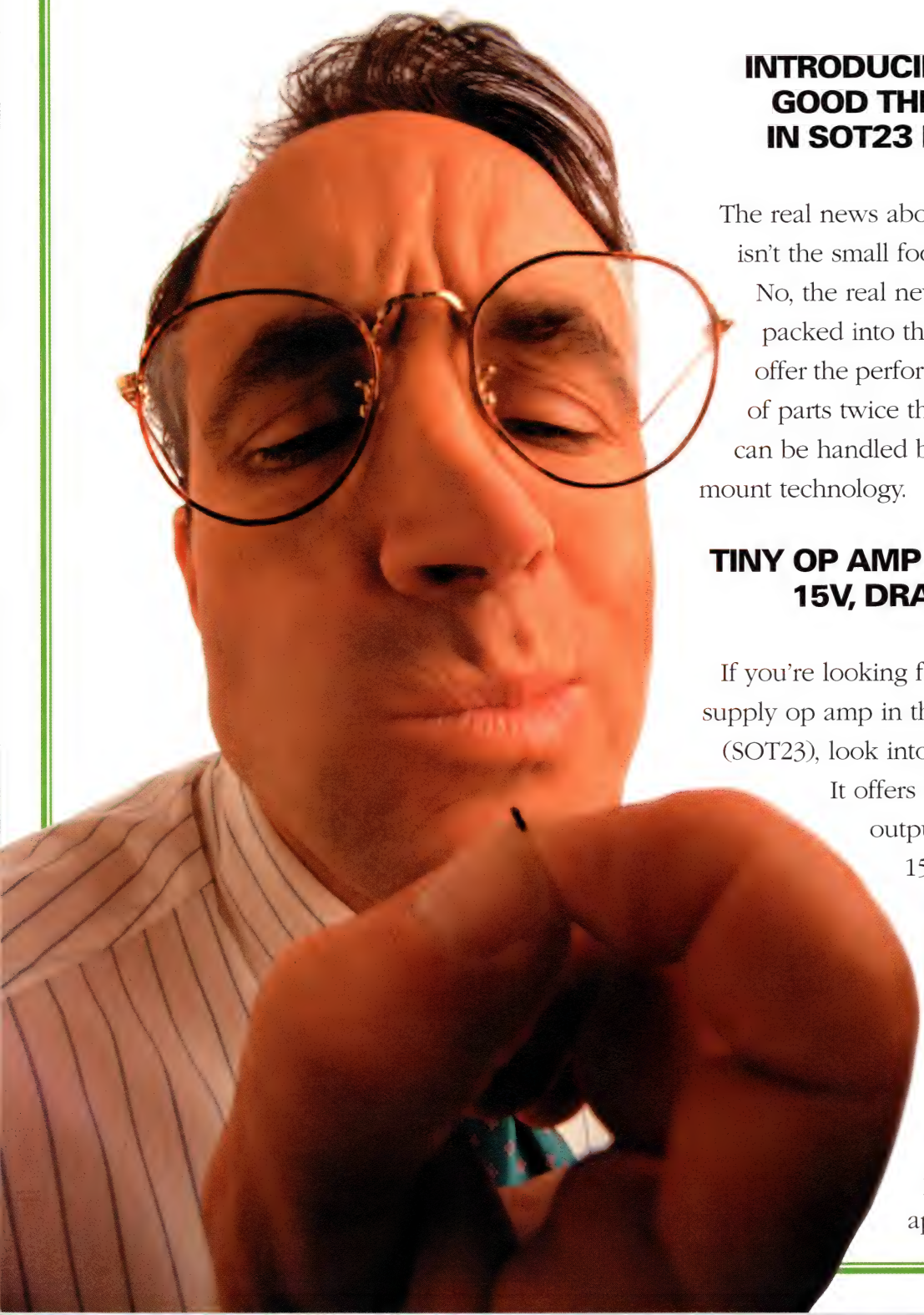


making waves

To take advantage of the latest wave of analog innovations, follow these simple instructions.

National Semiconductor™

1. Squint.



INTRODUCING TINYPAK. GOOD THINGS COME IN SOT23 PACKAGES.

The real news about National TinyPak™ isn't the small footprint SOT23 package. No, the real news is the power we've packed into them. Our Tiny devices offer the performance and functionality of parts twice their size. And TinyPak can be handled by standard surface mount technology.

TINY OP AMP RUNS ON 3V TO 15V, DRAWS 0.5mA.

If you're looking for the best single supply op amp in the smallest package (SOT23), look into the TinyPak LMC7101. It offers rail-to-rail input and output, operates on 3V to 15V and draws a low 0.5mA of current. This unbeatable combination of size and performance makes the LMC7101 the perfect choice for a wide variety of portable and handheld applications. And at $0.84

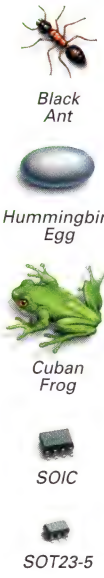
(1000 unit), even the price is tiny. (Also available in plastic DIP package.)

TINY TEMP SENSORS OFFER +10mV/°C SENSITIVITY FROM -20°C TO +100°C.

Think of the LM45 temperature sensor as a Tiny alternative to thermistors. The LM45 operates on 4V to 10V power supplies. Its specified temperature range is -20°C to +100°C with output scale factor of +10mV/°C, a guaranteed accuracy of +/-2°C at 25°C and low power of 120µA maximum. It's designed for single power supplies and requires no external calibration signal conditioning or linearization. Although the LM45 is Tiny, it's destined to play a large role in applications from battery and microprocessor power management to process and HVAC control. LM45 prices start at $0.90 (250 unit).

TINYPAK VOLTAGE REFERENCES WITH PRECISION OUTPUT FROM 1.2V TO 10V.

Here are two more Tiny wonders. The LM4040 and LM4041 precision voltage references offer fixed output of 1.2V, 2.5V, 4.096V, 5V, 8.192V, 10V or adjustable output from 1.24V to 10V. Both offer +/-0.1% to +/-2.0% output tolerance. Neither requires an external output capacitor. And with pricing starting at $0.92 (100 unit), these TinyPak (SOT23) references are becoming very big hits.



How small is our TinyPak? So small it makes ants look as big as aardvarks and SO8s look, well, a whole lot bigger than they used to look.

OUR LOW DROPOUT REGULATOR IS TINY. SO IS ITS 120mV DROPOUT VOLTAGE.

The LP2980 minimizes board space and maximizes battery life. It offers fixed outputs of 3.0V, 3.3V and 5.0V, a dropout voltage of 120mV at 50mA and a quiescent current of 375µA at 50mA. You can select output precision of +/-0.5 or +/-1.0%. And in shutdown mode, the quiescent current is less than 1µA. This big performance combined with its small size and price—$0.77 (1000 unit)—make the LP2980 perfect for battery-powered applications from cellular phones to notebook computers.

2. Open your ears.

MEET BOOMER. 1W AUDIO FROM 5V.

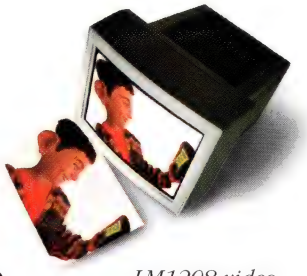
Want your innovation loud and clear? Listen to National Boomer® (LM4860 and LM4861). The LM4860 delivers a thundering 1W of output power (1/2W for the LM4861) into an 8Ω load, with less than 1% THD+N from a 5V supply. It requires no external capacitors or snubber circuits. And in shutdown mode it typically draws less than 1µA. All of which makes Boomer the sound solution for everything from PCs to games to cellular phones. And the LM4860 price is a very quiet $1.99 (1000 unit), $1.89 for the LM4861.

OVERTURE AUDIO µPOTS SING. "CLICKLESS" LEVEL CONTROL.

Speaking of sound solutions, National Overture™ µPot audio attenuators, LM1972 (2-channel) and LM1973 (3-channel) bring clearer, purer sound to high-end audio applications, from studio equipment to home entertainment systems. Both devices offer 110dB minimum signal-to-noise ratio, 110dB typical channel separation and an astounding typical 0.0008% THD+N.

Each channel consists of a resistor ladder which provides 0.5dB steps near unity, with larger steps as attenuation increases. Mute attenuation is typically 104dB. And these devices can be daisy-chained to a single microcontroller for automation of mixing consoles. At $2.85 (1000 unit) for the LM1972 and $3.05 for the LM1973, they sound even better.

OPEN YOUR EYES, TOO. MATCHED COLOR FROM OUR XGA VIDEO PREAMPS.

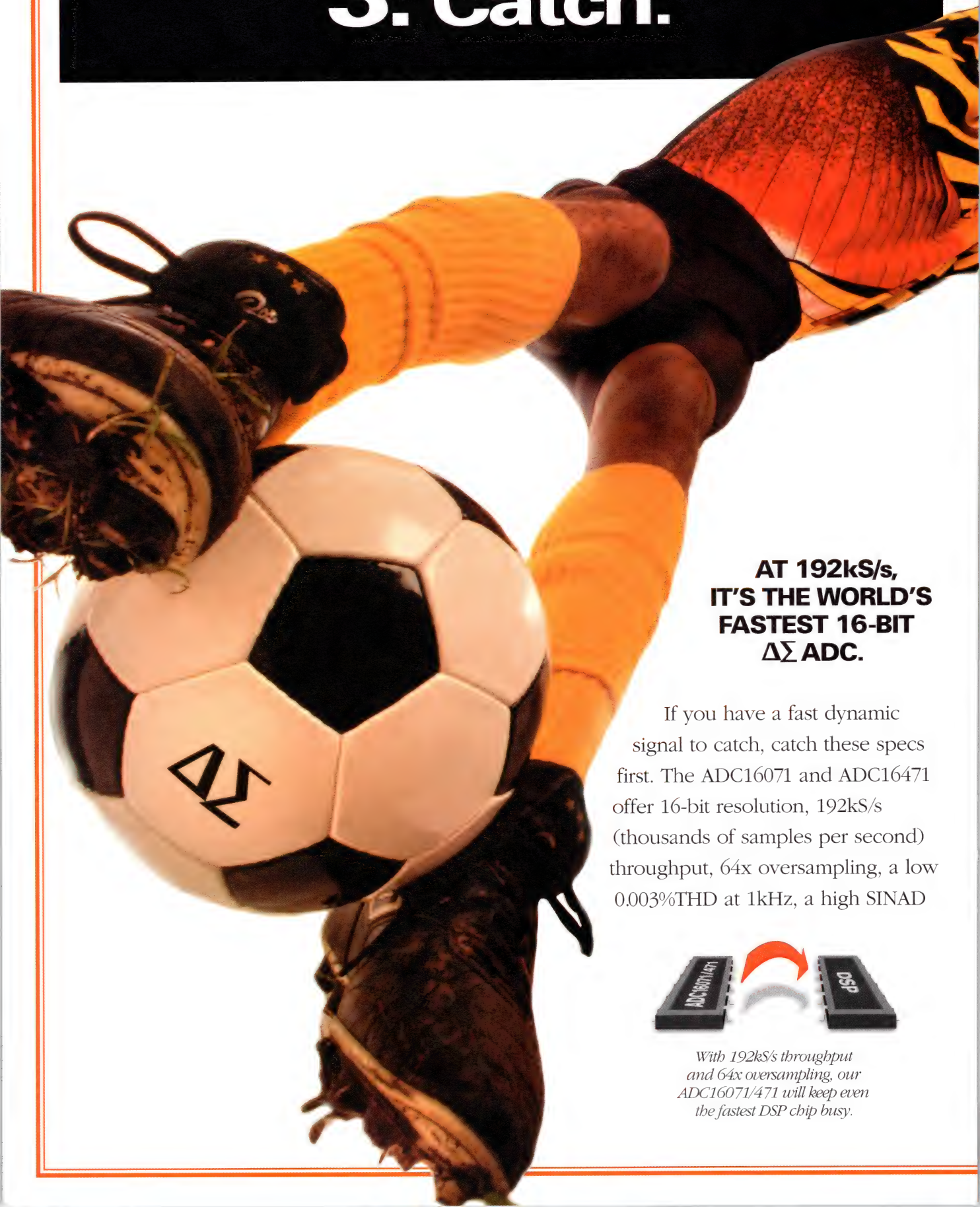


LM1208 video preamp gives you greater control over each color channel, and gives users the ability to perfectly match video color to output color.

Here are a pair of video preamps designed to cover your XGA monitor needs.

The LM1208 features 130MHz bandwidth with 40dB drive control range (highest available) for high-end applications. The extended range gives greater dynamic control of individual color channels, enabling users to match CRT color to that of other output devices. For low-end XGA applications, the LM1207 offers an 85MHz bandwidth with 6dB of drive control. Both parts have on-chip blanking. And all DC control inputs operate over 0 to 4V range for easy interface. The price looks good, too, at $2.20 (1000 unit) for the LM1207 and $2.50 for the LM1208.

3. Catch.



AT 192kS/s, IT'S THE WORLD'S FASTEST 16-BIT ΔΣ ADC.

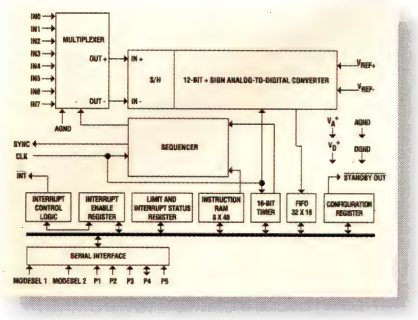
If you have a fast dynamic signal to catch, catch these specs first. The ADC16071 and ADC16471 offer 16-bit resolution, 192kS/s (thousands of samples per second) throughput, 64x oversampling, a low 0.003%THD at 1kHz, a high SINAD

With 192kS/s throughput and 64x oversampling, our ADC16071/471 will keep even the fastest DSP chip busy.

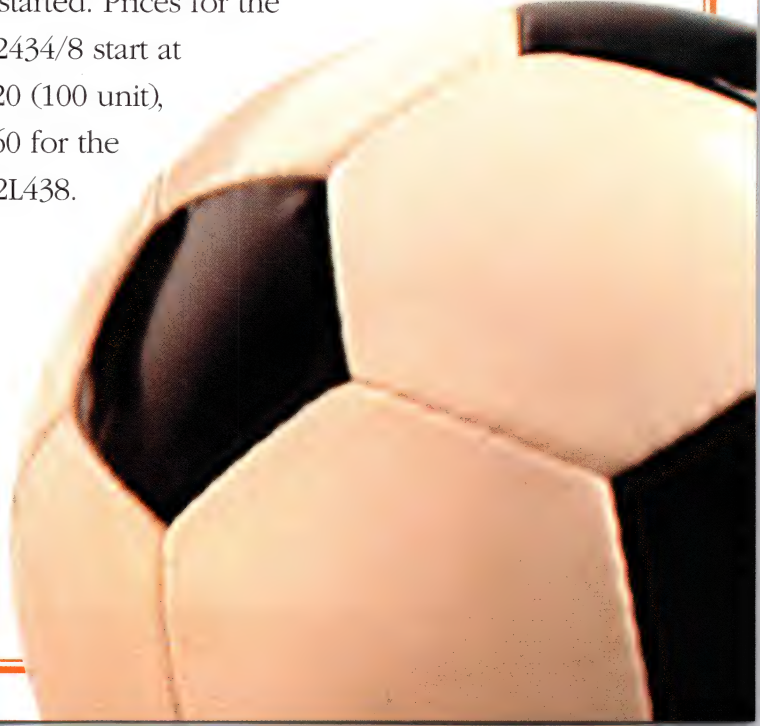
of 80dB min at 48kS/s, a great speed/power ratio of 275mW at 48kS/s and shutdown capability, all from a 5V supply. And the ADC16471 has an on-chip reference. Sounds like the perfect performance for a lot of high-end applications like, say, DSP front-ends, acoustic and vibration analysis, telephony, voice recognition and audio. At $17.80 for the ADC16071 (100 unit) and $18.50 for the ADC16471, they're going fast.

AND AT 140kS/s, WE'VE GOT THE WORLD'S FASTEST SERIAL I/O DAS, TOO.

The new 12-bit LM12434 and LM12438 serial I/O data acquisition systems are screamers. The LM12434/8 delivers 140kS/s throughput while consuming only 40mW from a 5V supply, while the LM12L438 hits 105kS/s consuming 20mW from 3.3V. Both devices are true systems-on-a-chip. They feature a user-programmable sequencer, require zero glue logic and connect directly to National Microwire™/PLUS, SPI/QSPI, TMS320, I²C, 8051 and SCI interfaces, so they're quick and easy to design with. And speaking of easy, we offer National WaveVision,™ our powerful Windows®-based design evaluation software, free to get you started. Prices for the LM12434/8 start at $18.20 (100 unit), $17.60 for the LM12L438.



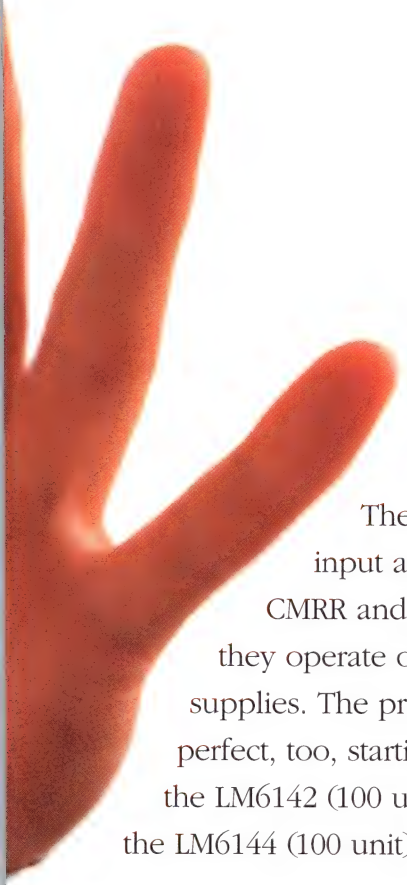
Our new LM12438 contains everything you need to build a complete data acquisition system—all on a single chip.



4. Do more. Eat less.

OP AMPS DO 17MHz GBW. EAT ONLY 650µA.

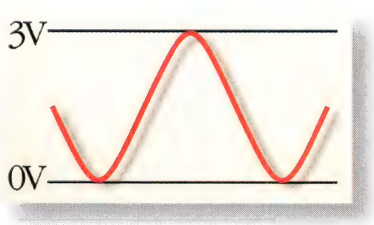
Introducing the world's most perfect single supply op amps. Namely, the LM6142 (dual) and LM6144 (quad). Both devices deliver an astounding 17MHz gain-bandwidth at 50kHz (enough to replace several of your not so perfect op amps) while drawing just 650µA/amplifier



of supply current. They offer rail-to-rail input and output, 107dB CMRR and PSRR=87dB, and they operate on 1.8V to 24V supplies. The prices are nearly perfect, too, starting at $2.34 for the LM6142 (100 unit) and $3.62 for the LM6144 (100 unit).

TINY VIDEO OP AMPS BRING BIG PERFORMANCE TO SINGLE SUPPLY SYSTEMS.

The LM7131 may come in a TinyPak (SOT23-5), but its performance is huge. Designed to bring high performance video to battery-powered and desktop systems, the LM7131 specs are guaranteed at 3V, 5V and +/-5V. With a 70MHz gain-bandwidth at 5V, it delivers solid video performance. And with typical supply currents of 7.0mA at 5V and 6.5mA at 3V, it's easy on batteries. The LM7131 is ideal for everything from driving flash A/D converters and back-terminated video cables to portable and desktop computer video output, desktop teleconferencing, multimedia boards and even digital audio. The LM7131 is available in SO8 and DIP packages as well as the TinyPak. And the price starts at a tiny $1.00 (100 unit).



The LM6142/44 and LMC6462/64 low power op amps deliver rail-to-rail performance.

THE WORLD'S LOWEST POWER, HIGH PERFORMANCE 3V TO 15V RAIL-TO-RAIL I/O OP AMPS.

With their incredibly low supply current of 20µA per channel, the LMC6462 (dual) and LMC6464 (quad) set the low power standard for 3V to 15V op amps. Both devices deliver rail-to-rail input and output, an ultra low input current of 10pA max, high voltage gain of 128dB and low offset voltage of 0.5mV max. All of which makes them perfect for battery-powered applications, including cellular phones, notebook computers, PDAs and portable instruments. All at prices from $2.10 (100 unit) for the LMC6462 and $2.50 (100 unit) for the LMC6464.

5. Squeeze here.

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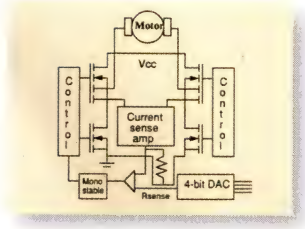
The LMD18245 is a fully integrated 3A H-Bridge motor driver that greatly simplifies system design by including everything you need on chip. What it includes is pulse width modulation (PWM) in the form of fixed off-time pulse control, a 4-bit DAC for easy motor stepping and current control, and device protection through thermal shutdown, current limit and undervoltage lockout. It features a low Rdson of .3Ω per switch and its LMDMOS advanced IC process delivers



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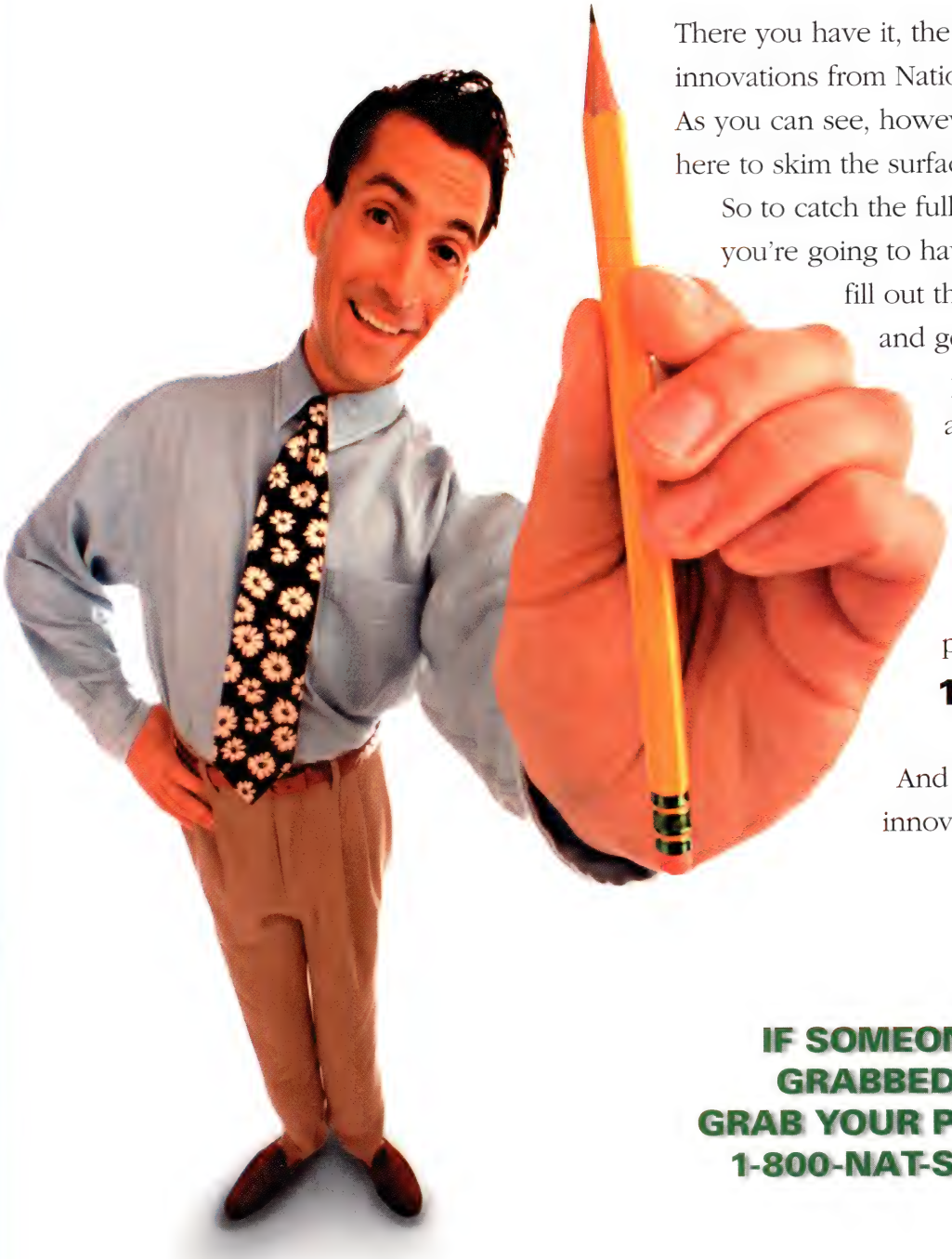

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RFID tags connect smart cars to smart highways

GARY LEGG, EXECUTIVE EDITOR

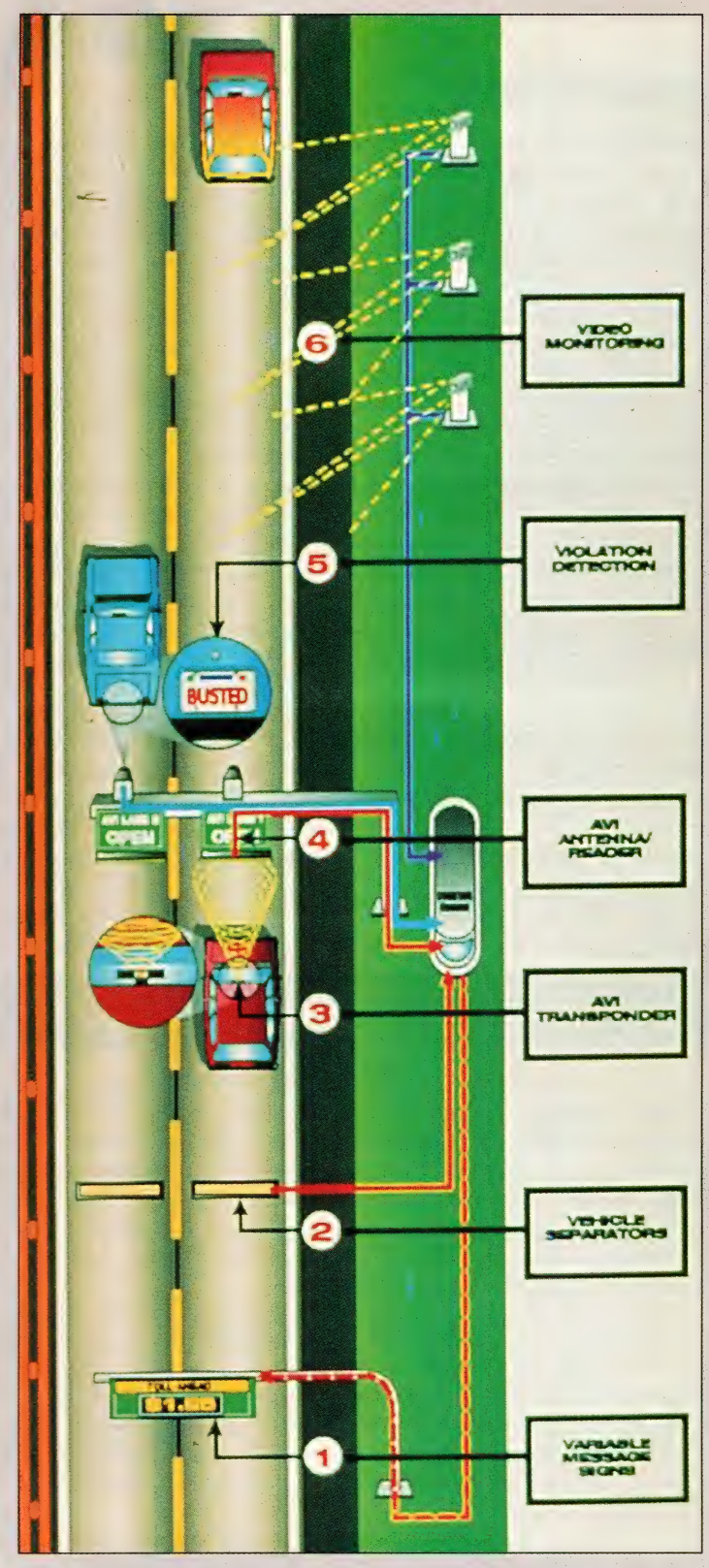
Small RF identification (RFID) tags are part of the critical communication link between automobiles and electronically directed "smart" highways. Other uses for RFID are increasing rapidly.

On an average day, 225,000 vehicles travel on California State Route 91, connecting Orange and Riverside counties. Sometimes, traffic is so heavy a driver can spend two or three hours traveling 10 miles. And, within 15 years, according to estimates, traffic on SR-91 will increase by 50%.

Fortunately, highways are getting some help from electronics to deal with heavy traffic. A year from now, part of SR-91 will be a "smart" highway, maintaining automatic, two-way electronic communication with cars to help traffic flow more smoothly. Cars on SR-91 will be smart, too, thanks largely to a simple communication device called an RFID tag.

When the SR-91 control system queries them, the RFID tags act simply as transponders that send short, unique codes. As the heart of future smart highways, the tags' essential function, automatic vehicle identification (AVI), provides information that makes traffic flow more smoothly and quickly. The system can electronically collect prepaid tolls, for example, eliminating the need for motorists to stop or even slowdown at toll booths. Traffic will move more quickly, fuel economy will improve, and pollutants will decrease.

On SR-91, an RFID tag on a vehicle's dashboard will enable a motorist to travel in toll lanes, now under construction, that will be off-limits to the hordes of nonpaying motorists. The transponders will communicate with the highway's control system via antennae on gantries over the roadway. A series of gantries at strategic locations will connect with the larger system via a fiber-optic backbone. MFS Network Technologies (Omaha, NE, (402) 342-2052) is designing the system.



Cars on smart highways, communicating with RFID tags, will provide information to highways' control systems that can help traffic flow more smoothly. (Graphic courtesy of MFS Network Technologies)

Although RFID tags aren't new (see **box**, "The growing world of RFID," and **Ref 1**), the transponders on SR-91 will move commercial RFID technology into new areas. Until now, most RFID

SMART HIGHWAYS

tags have operated over maximum ranges of only 2 to 3 ft, using frequencies around 125 kHz. The SR-91 transponders, however, must work over ranges of 20 ft or more. In addition, to work with fast-moving cars, they must receive and send information rapidly.

For longer ranges and higher transmission rates, RFID tags must operate at high frequencies. The SR-91 transponders, for example, which Texas Instruments' Registration and Information Systems (TIRIS) Division developed, use FM transmissions in a band from 902 to 928 MHz. The California Department of Transportation specified this band, largely because of plentiful and inexpensive components for use in 900-MHz consumer products.

Each SR-91 transponder is about the same length and width as—but thicker than—a 3.5-in. floppy disk. Unlike smaller, low-frequency tags, which rectify and store received RF energy to power their own transmissions, each SR-91 tag contains a long-life battery. The battery also powers 128 bits of SRAM, which contains the device ID and other information. Each tag costs about $30 to $35.

In the most basic operational step, an RFID transponder simply responds to a query from the SR-91 control system. The system asks for the transponder's identity, and the transponder replies by sending a code programmed in its memory. The system then searches its database for that identity and grants appropriate privileges—for example, tollway access to a paid-up toll customer.

A system can also write to an RFID tag's memory, although SR-91 won't initially use that capability. By modifying stored values—for example, by debiting a stored account balance—the system can perform tasks such as accepting electronic "tokens" without involving the system database. The process takes as little as 20 msec.

To work with moving vehicles, an RFID system must be fast. The transmission rate to and from SR-91 RFID transponders is 300 kbps, allowing a one-way, 128-bit transmission in less than 0.5 msec. System protocols consume additional time, however, and multiple read operations are sometimes necessary to guarantee correct operation. The specification for SR-91 requires 40 reads while a vehicle is in the antenna's footprint, or field, guaranteeing that the system will work with vehicles traveling as fast as 150 mph.

In a system as complex and dynamic as a smart highway, RFID must work reliably. It can neither allow vehicles to go undetected nor incorrectly identify vehicles. It must distinguish vehicles traveling close to each other and vehicles that are changing lanes. It must not cause significant EMI, but it must tolerate interference. And, finally, it must operate at low power levels. (Permissible power levels vary, according to requirements that regulating bodies of different countries set. Europe has plans for several smart highways.)

To achieve good noise immunity at a relatively low cost, the RFID tags for use on SR-91 use FSK transmission. Phase-shift-keying and spread-spectrum techniques offer better noise immunity, but at significantly higher prices. To guarantee data integrity, each transmission uses a 16-bit cyclic-redundancy check. Unless there is agreement in all steps of

THE GROWING WORLD OF RFID

The use of battery-operated, high-frequency RFID tags on smart highways deviates from RFID's more typical applications. Most RFID tags are tiny and operate at relatively low frequencies, typically around 125 kHz. In addition, by rectifying received RF energy and storing it in a small capacitor, a low-frequency tag powers its own response transmissions without a battery. The combination of size and battery-free operation makes RFID useful just about anywhere.

Ford Motor Co, for example, prevents car theft by embedding a passive (no-battery) RFID tag in the ignition key of some of its European-made cars. When someone inserts a key in the ignition and turns it, an antenna in the steering column polls the RFID tag for its unique identity. Without the tag's response, the car's engine-control computer shuts down, and the car stops running. The system is virtually impossible to bypass, according to Ford.

In the near future, key-embedded RFID tags may even customize cars for drivers. For example, a husband and wife could have separate keys with RFID tags programmed with preferences for seat adjustment, climate control, and so forth. Simply turning on the ignition would provide the settings the driver normally wants. Ford is planning to use RFID in some of its American-made cars, but it's not saying when or what capabilities will be available.

A common use for RFID tags is in livestock and animal control. A device resembling a large hypodermic needle inserts a tag encased in a minuscule glass capsule (about 4×30 mm) under the skin of an animal's neck. The tag holds the animal's identity and perhaps additional information, such as vaccination records. To identify the animal and to store or retrieve information about it, someone need only "scan" the animal with a handheld device within a distance of about 3 ft.

In Europe, RFID tags assist in metered trash collection. When a garbage truck lifts a trash receptacle and weighs it, a device on the truck reads RFID tags on the trash receptacles. The RFID tags provide customer and trash-weight information, which the trash collector uses to bill the customer.

Mounted on security badges, RFID tags can control access to facilities. On a key fob, a tag can authorize fuel refilling for a fleet truck or taxi. Attached to assembly components in factories, tags can provide routing information and assembly documentation and instructions. Strapped to the wrist of a marathon runner, a tag can speed processing at the finish line.

Low-frequency RFID tags are also cheap. Because they don't require high-speed circuits or batteries, some sell for as little as $2 to $3 in large quantities.

The future also holds much in store for high-frequency RFID tags, however. In addition to tags already operating in the 900-MHz band, future tags will operate at 2 GHz or even higher. In the United States, several companies are lobbying the FCC for approval of tags that operate at 2.45 GHz. In Europe, plans are under way for 5.8-GHz tags.

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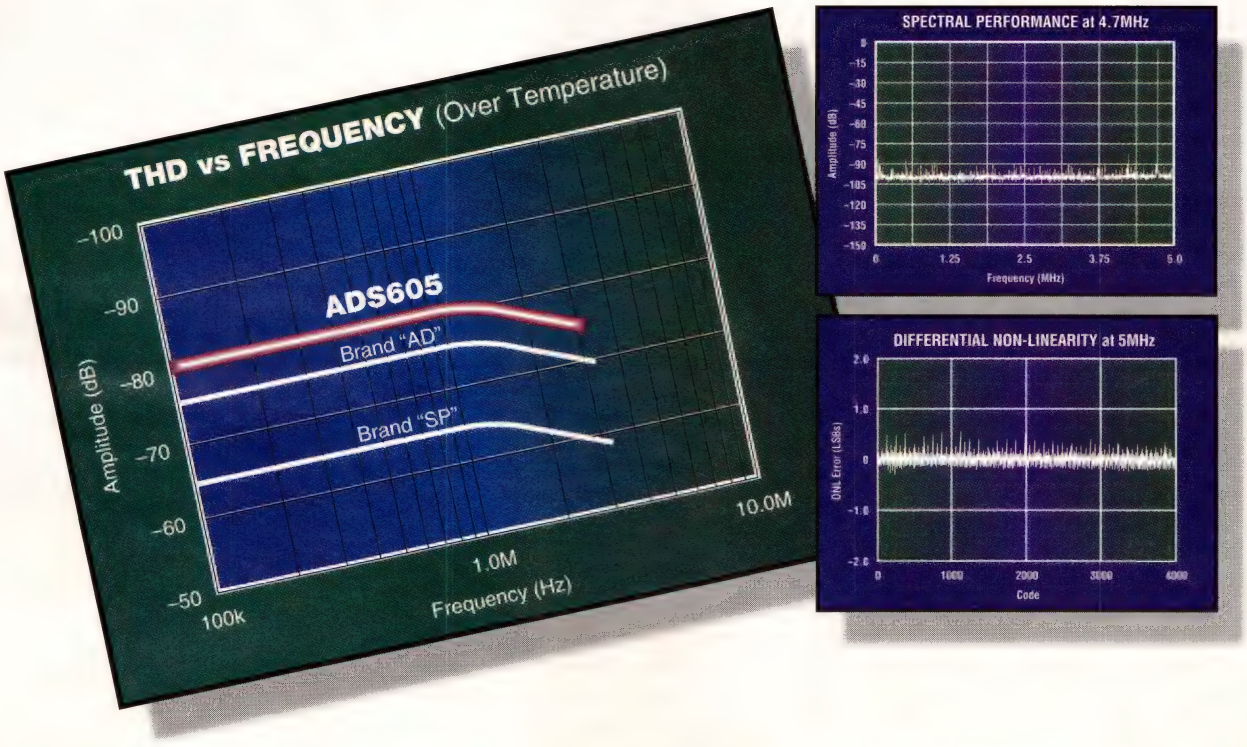

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a cycle—a poll by the system, a response by the transponder, and an acknowledgement by the system—a "no-read" indication results.

Antenna orientation determines footprint and thus affects the system's ability to distinguish one vehicle among many. Instead of being oriented for maximum read range (50 to 100 ft), each SR-91 antenna has a footprint that covers only a short segment of a highway lane. An antenna on an 18-ft gantry typically has a 12- to 15-ft-wide footprint to cover a 12-ft lane. If the gantry is at a toll station, where cars may be in a line, the footprint typically is 15 to 20 ft long. On an open stretch of highway, the footprint may be as long as 25 ft.

Avoiding simultaneous responses from RFID tags on numerous vehicles requires some clever techniques. For example, after a successful cycle of poll, response, and acknowledge, an RFID tag turns off for 10 sec. While the tag is off the vehicle, it is usually identifying travels well out of the antenna's footprint; during that time, the tag does not respond to further polls.

Synchronizing antennae helps differentiate among cars in adjacent lanes. Antennae for different lanes take turns polling, and each operates at a slightly different frequency, usually 2 to 4 MHz away from the frequencies of nearby lanes. By observing the time and frequency of an RFID tag's response, the system can tell in which lane a car is traveling.

Automatic toll collection is a common function on smart highways. As a car approaches a toll station, a sensor (1) embedded in the pavement notifies the highway-control system. An RFID tag (2) on or near the car's dashboard stores the car's identity and a prepaid toll amount. An antenna (3) sends an RF signal to the tag and receives the car's identity in response. The system may also write data back to the tag via the antenna. A roadside receiver (4) collects data, classifies vehicles, and transmits information back to a central station. An enforcement camera (5) takes a picture if a vehicle doesn't pay the correct toll. (Graphic courtesy of Texas Instruments)

In tests, the SR-91 system has identified two vehicles traveling in separate lanes within 1 ft of each other. It can also identify two motorcycles traveling side by side in one lane, even when they are switching lanes. The SR-91 system correctly identifies 99.95% of the vehicles it encounters, according to TIRIS general manager Dave Slinger. For the few vehicles the system doesn't identify, a video system captures an image of the vehicle's license plate and invokes human intervention.

AVI with RFID not only collects tolls but also collects different toll amounts, according to the type of a vehicle and its use. RFID can also help correlate trucks' identities with their weights as they pass over weigh-in-motion systems embedded in highway pavement.

In time, smart highways will automatically direct traffic in response to accidents, construction, or inclement weather. The SR-91 project, in fact, includes programmable highway signs for that purpose. Although SR-91 is limited in scope, it establishes the critical link between highways and cars that have the beginnings of intelligence. EDN

Reference

1. Legg, Gary, "Small rugged memories put data where it's needed," *EDN*, Aug 20, 1992, pg 99.

You can reach Executive Editor Gary Legg at (617) 558-4404, fax (617) 558-4470.

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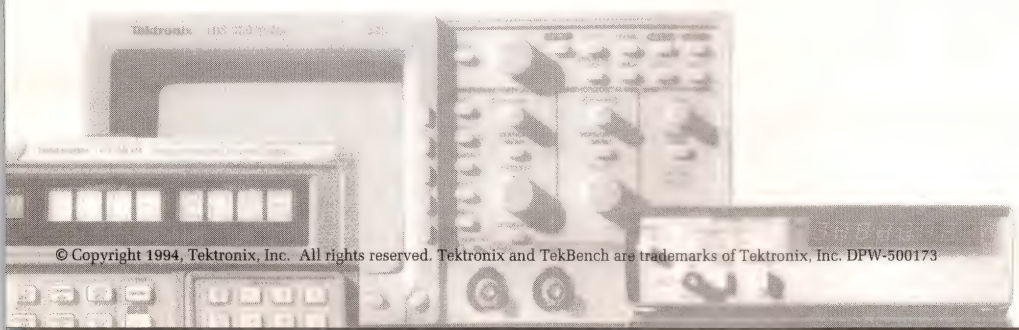

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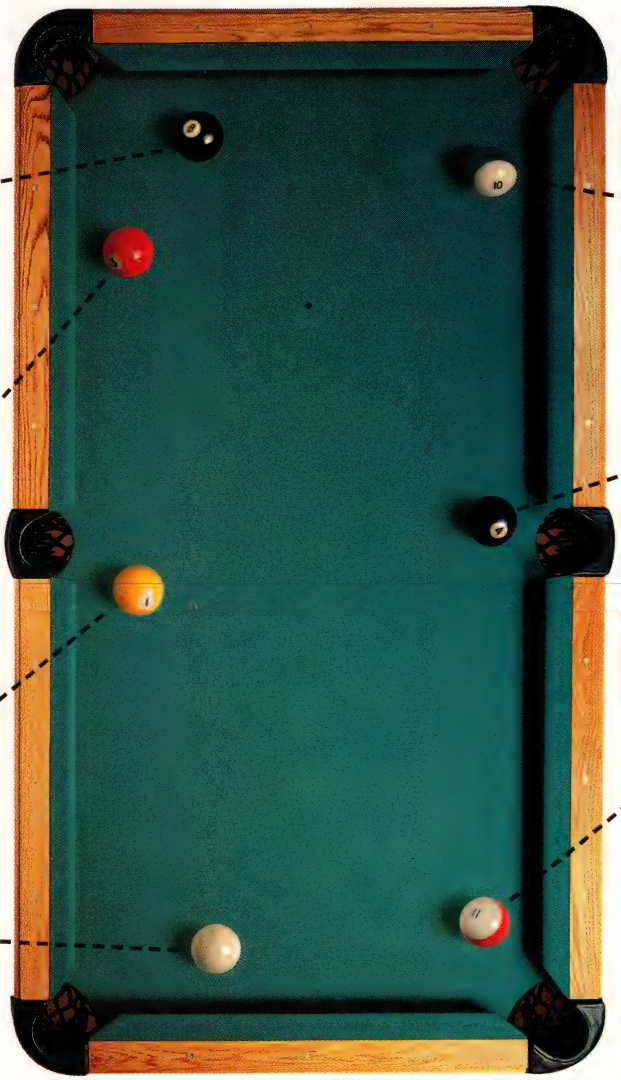

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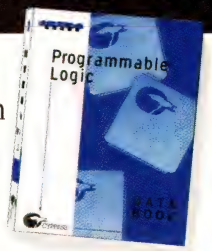

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Building the digital-video pipeline

Image compression continues to occupy the limelight, but a commercial digital-video system will need additional advanced technologies. One requirement is a practical way to deliver high-speed digital signals over existing channels.

RICHARD A QUINNELL, TECHNICAL EDITOR

Image compression has received a great deal of attention as a key technology for making digital video practical. But compression is only one part of the answer. Putting digital video into the consumer's hands also requires a delivery method that utilizes existing wiring and cable. Digital-video transmission is one unsung technology that's evolving to fill this need.

Digital video is already demonstrating its acceptability in the marketplace. Broadcasters, cable companies, and telephone companies are actively conducting field trials in a variety of locations, including northern Virginia, the San Francisco Bay area, New York City, and Orlando, FL. These trials are using direct digital-transmission media such as fiber optics and ISDN telephone lines.

In the San Francisco Bay area, for example, television-station KRON (Chronicle Broadcasting) is using MPEG-1 compression hardware and software from FutureTel and T1 digital telephone lines to distribute KRON's BayTV cable channel to a number of cities. Digital video travels to local cable-TV headends over the phone lines. The cable stations then convert the signal to traditional analog form for local distribution.

Although these trials demonstrate the acceptability of digital video to consumers, many television-industry observers see digital telephony as only one step toward widespread digital-video distribution. Few consumers have high-bandwidth digital links to their homes, and the numbers are not increasing rapidly. Despite the publicity, ISDN telephony is still many years from widespread availability.

Entertainment providers realize that for digital video to become a commercial success, existing analog cable networks and broadcast channels must be customized to handle high-speed digital signals. As an added bonus, if those networks can handle digital data, they can also serve as pathways for computer communications, providing additional market opportunity.

Therefore, there is a relatively unheralded push to develop technology for packing digital data into existing media. The best known effort has been the drive to create a digital HDTV that is bandwidth compatible with existing broadcast TV. Other, quieter efforts are also underway to use standard telephone and cable-television services as the digital channels.

Broadcasters are testing digital video in a number of field trials, such as this one from television-station KRON in San Francisco. Early results show that, although compression artifacts appear in the video, consumers have few complaints.

DIGITAL-VIDEO TRANSMISSION

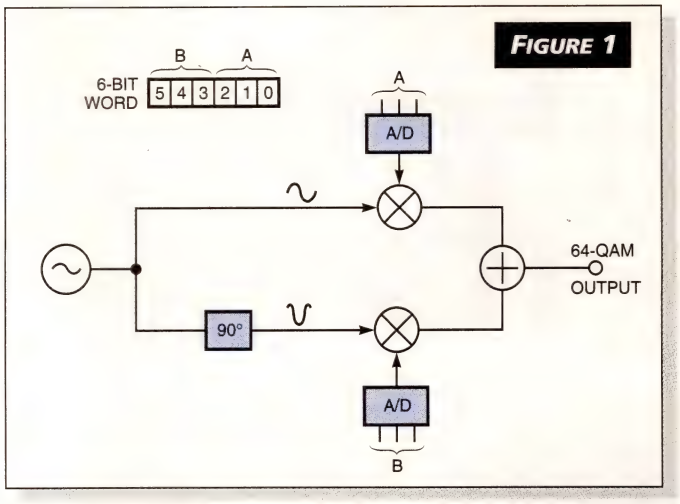
These existing channels present a number of barriers to digital-information transmission. For one, their bandwidth is limited. Twisted-pair telephone wiring has an effective bandwidth of approximately 500 kHz over a three-mile distance. Broadcast-television channels are constrained to a 6-MHz bandwidth. Satellite-transponder channels are typically 36 MHz wide. An average cable-TV distribution network has a bandwidth of 350 to 700 MHz.

Other barriers include the channels' abilities to maintain signal integrity to the precision needed. Broadcast signals suffer from reflections and multipath distortion. Telephone and cable networks generate multiple reflections from impedance mismatches that change frequently as receiver units connect and disconnect from the network. Satellite broadcasts are power-constrained, resulting in low S/N ratios.

Coding bypasses bandwidth limits

The major concern, however, is the mismatch between digital-video bit rates and channel bandwidth. Nyquist showed that the bandwidth of an ideal pulse is the reciprocal of the pulse width. Assuming that data pulses are to be as wide as possible, for example, equal to the pulse period, channel bandwidth is equal to signal-pulse rate. Thus, a straight bipolar digital signal, such as a typical logic signal, occupies a bandwidth equal to the data bit rate. A raw full-color, digital-video signal needs a minimum of 30 Mbytes/sec to achieve full resolution—a bandwidth of 240 MHz. Only the cable system would appear to have sufficient capacity to carry digital video.

The key to using the consumer signal channels, then, is compacting digital signals so that they fit within the channel's bandwidth. MPEG compression can lower digital-video's data rate to 1.2 to 1.5 Mbps while maintaining acceptable picture quality. This fits within cable- and broadcast-channel bandwidths, but it provides digital video with no particular advantage over analog. And, without further compaction, the digital bit rate exceeds the typical bandwidth of existing consumer telephone channels.



Quadrature amplitude modulation (QAM) uses two carriers with a 90° phase shift to encode data without adding signal bandwidth. Each carrier is independently modulated.

Fortunately, Nyquist's bandwidth calculations only constrain the signal's pulse width, not its amplitude. If the signal pulse employs a multilevel code, its information-carrying capacity increases without adding bandwidth. In information theory, Shannon's Limit states that the information-carrying capacity, C, of a channel with bandwidth, W, signal power, S, and random-noise power, N, is

$$C=W\times\log_2(1+\{S/N\}).$$

For a 10-dB S/N ratio channel, therefore, as many as 10 bits can be transmitted for each Hz of channel bandwidth. The trick is to encode the data within a single pulse.

Codes utilize information capacity

The choice of an encoding scheme depends on a number of factors. Primary factors are the transmission medium's bandwidth and S/N ratio. The coding scheme's susceptibili-

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DIGITAL-VIDEO TRANSMISSION

ty to interchannel interference, decoding costs, and ability to handle multipath and reflections are also important. To date, at least three major schemes have been developed to handle digital-video transmission.

The first and most well-developed scheme is quadrature amplitude modulation (QAM). For a number of years, this scheme has been used in microwave telecommunications. It has also been the modulation method of choice for high-speed digital modems over standard twisted-pair telephone lines. See **Fig 1** for a block diagram of a QAM modulator.

QAM uses two carrier waves of the same frequency in quadrature—that is, with a 90° phase shift between them. The modulation scheme takes data in two groups of two, three, or four bits to drive two ADCs. The two ADCs amplitude-modulate the two carrier waves. The QAM output signal is the sum of the two modulated carriers.

A plot of the resulting waveform in complex vector coordinates yields a constellation of points, one for each possible data bit pattern. Thus, a QAM signal using two groups of 3 bits at each modulation step produces a constellation of 64 points in complex coordinates (**Fig 2**). The signal carries six data bits for each Hz of bandwidth.

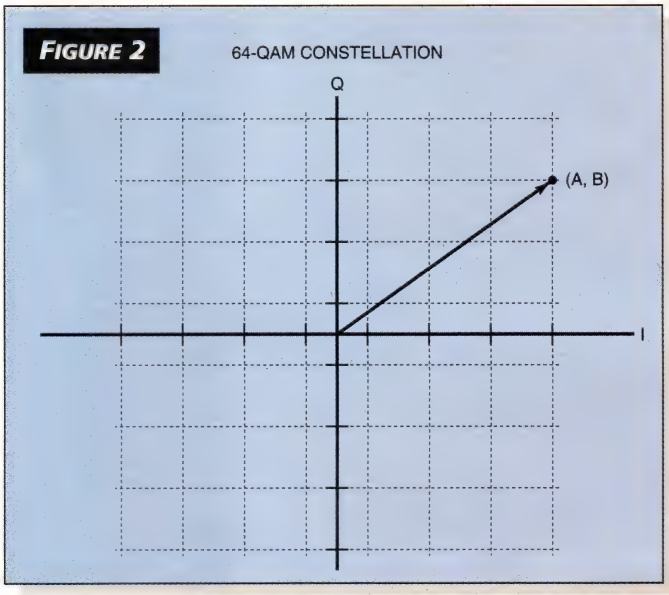
A competing technology to QAM is the vestigial-sideband (VSB) modulation scheme, which Zenith proposed for spectrum-compatible HDTV. VSB technology uses multilevel amplitude modulation on a single carrier, then filters the signal to remove most of the lower modulation sideband. VSB provides only a one-dimensional vector pattern—versus QAM's two-dimensional approach. However, because VSB uses only a single modulation sideband, its spectral efficiency is equivalent to that of QAM.

AT&T Paradyne developed a third modulation scheme, carrierless amplitude-phase (CAP) modulation (**Ref 2**). CAP is a variation of QAM that uses direct digital-signal generation rather than modulating a carrier wave (hence, carrierless in the name). CAP modulation separates data into two groups, using one group to specify the imaginary component of the signal vector. The other group specifies the real component. The vector, which changes at the data symbol rate, passes through a pair of digital bandpass filters with the same amplitude responses—but phase responses that differ by 90°. The final output signal is the sum of the two digital-filter-output signals passed through an A/D converter.

QAM is established technology

In the race to deliver these technologies to the consumer's set-top decoder box, QAM has a decided advantage. The technology is well-established, having been used for years in microwave links and high-speed modems. Further, there are now monolithic ICs available that implement a QAM decoder for video signals.

One such chip set comes from the joint efforts of Broadcom Corp and Scientific Atlanta. The QAMLink chip set includes a QAM demodulator IC, an adaptive equalizer, and a synchronization IC that provides digital loop filters and phase detectors for the digital phase-locked signal recovery loops. The chip set is capable of handling 64- or 256-symbol QAM, corresponding to 6 or 8 bits per Hz of channel bandwidth.



By interpreting the two quadrature carriers as the real and imaginary components of a complex vector, a QAM decoder maps the incoming signal into a constellation of points. Each point corresponds to several data bits.

Such bit densities allow a 6-MHz video channel (5 MHz after filter rolloff) on cable systems to carry 30 to 40 Mbps of digital data—enough for 20 MPEG-1 or 10 MPEG-2 video data streams. Thus, a typical 350-MHz cable system bandwidth could handle as many as 500 MPEG-2 video channels using the QAMLink chip set. Even a 350-kHz telephone channel could carry a single MPEG-1 channel.

The impact of such information capacity on the home goes beyond the frightening ability to have all episodes of "I Love Lucy" running simultaneously. The information received at the set-top box is all digital and need not represent video. Thus, the advent of high-speed video transmission opens a doorway for digital services of all forms to reach the consumer through the TV lead-in. EDN

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2. Prunty, Peter F, "Delivery of TV over existing phone lines," *SMPTE Journal*, September 1994, pg 586.

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REWRITABLE DATA-STORAGE SYSTEM PLAYS YOUR FAVORITE TUNES, TOO

With a portable, handheld unit the size of a Walkman, you can now access and store the equivalent of 100 floppies' worth of data on a single disk. You can also listen to music and update complex software files on the fly.

COURTNEY GRANNER

JAMES P LEONARD,
SENIOR ASSOCIATE EDITOR

You're scheduled to present your latest IC design to the rest of the team this afternoon. Using electronic-design-automation software and Sony's MD Data portable data-storage and -retrieval system, you put the finishing touches on the project and save the files on a 2.5-in. MiniDisc. At the presentation, you pop the disk into a portable MDH-10 disk drive attached to your laptop and pull off the design presentation without a hitch. After dinner, you grab the MDH-10, throw on a pair of headphones, and update your work while listening to your favorite concert bootleg or Beethoven symphony.

REWRITABLE DATA-STORAGE

With the MD Data system, which Sony introduced to OEMs in March, and the MDH-10, the first battery-operated, portable MD Data drive, 140-Mbyte, rewritable data storage and retrieval is easy and efficient. MD Data is a low-power, compact system based on Sony's MiniDisc digital-audio technology. With a 2.5-in. MiniDisc and a $699.95 MD Data system, you can record and rerecord disks more than 1 million times without loss of data integrity.

The MDH-10, which will make its retail debut in early 1995, is portable and compact; at 1.2×3.3×4.9 in., it's a bit smaller than a Walkman portable stereo. It suits a variety of business and consumer applications from notebook and laptop PCs to multimedia presentations.

Takashi Sugiyama, director of multimedia peripherals marketing for Sony Electronics, says that MD Data's portability and capacity improve the way users store information on the go. "MD Data is the first portable, high-capacity rewritable storage; it has the potential to be the floppy disk of the multimedia age," he says.

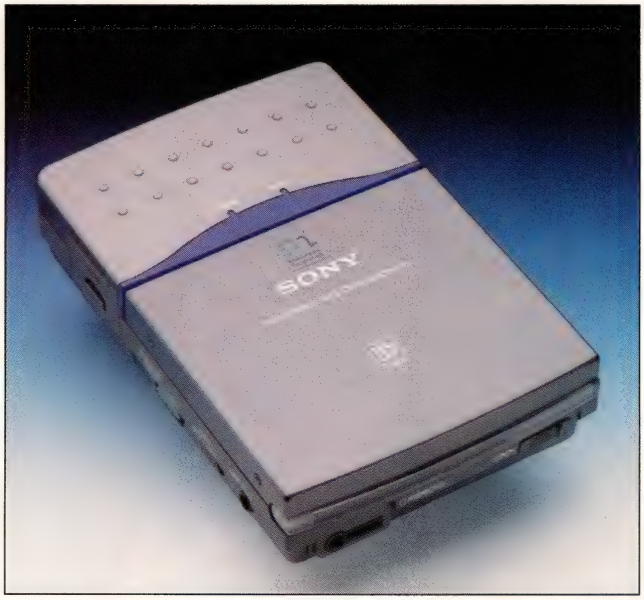
On-the-road convenience

What is revolutionary about MD Data is not its technology but its convenience and interoperability: The system's capacity is comparable to the amount of data you could store on 100 floppy disks. In addition, because the MD-10 is portable, mobile users simply plug it into their laptop and notebook PCs to create presentations, update client files, or play back multimedia applications anywhere. And, with lithium-ion batteries, you can run the unit for two hours before recharging.

"MD Data's portability and cross-development with audio means compatibility with additional application areas, such as in multimedia, where PC and audio integration are becoming the norm," says Sugiyama.

MD Data uses data compression to accommodate 74 minutes of playback, the length of a standard CD, onto its 2.5-in. disk format (see **box**, "1970s technology positions MiniDisc for 21st-century applications"). Media formats include rewritable magneto-optical for personal data-storage applications, read-only for electronic publishing (CD-ROM) and prerecorded-software applications, and hybrid (partially rewritable) for interactive applications (read-only parts prevent accidental erasure).

MD Data uses magneto-optical-disk technology to rewrite disks in a single pass, saving power. MD Data's recording density and linear velocity are comparable to standard CD technology. In addition, you can assign and reformat addresses after rerecording a disk.



MDH-10 is a portable data-storage and -retrieval unit that's a bit smaller than an average Walkman stereo. It features disk rewritability and, with a pair of headphones, lets you listen to music.

For portable applications, MD Data's hardware and disks are shock-proof. MDH-10 has a SCSI-2 interface to accommodate standard laptop, notebook, and subnotebook computers. MD Data's drive has a 150-kbps data rate and 300-msec average access time, significantly slower than the 15 msec of magnetic disk drives.

You power the system with a rechargeable lithium-ion battery pack, an ac power adapter, or three AA alkalines. MDH-10 comes with installation software for DOS/Windows and Macintosh systems; for $699.95, you also get a pair of headphones to use MD Data as a music MiniDisc player. MD-140 rewritable media costs $29.95.

Several software companies plan to work with Sony to develop products for MD Data. George Siegle, marketing manager for Deneba Software in Miami, says that Deneba's Canvas software for Macintosh and Windows systems teams nicely with the MD Data technology. Engineers use Canvas software for high-tech precision drawing, bit-map editing applications with detailed color graphics, and graphic design.

"A lot of our files are extremely large and sophisticated, and we're excited about MD Data because users can popin disks and easily transport their files," says Siegle. "Storing and retrieving large data files on floppies just isn't practical. Canvas users benefit from MD Data's large storage capacity. It's a convenient and fairly economical way to save and transport enormous amounts of information." Siegle also thinks that demand for MD Data in the business community will spread rapidly, based on the system's convenience.

MD Data also works well with WordPerfect's Envoy electronic-document-management system. MD Data and MDH-10 offer more storage capacity for Envoy, as well as a range of WordPerfect-related applications. With MD Data, users can store thousands of large, complex documents on one disk.

Graphic designers who work with Adobe Systems' Illustrator, Premier, and Photoshop software can also benefit from using MD Data. Such users typically experience frustration with files too large to save and transport via floppy disk. MD Data's capacity and portability offer artists and designers a compact data-storage alternative.

Sony has tentative plans with Microsoft to develop MD Data file systems for MS Word and Windows NT and Windows 95 operating systems. At IBM, designers are modifying MD Data's internal drive for ThinkPad mobile computers, accommodating multimedia peripherals, such as CD-ROMs and hard disks.

Additional uses for MD Data include photocopiers, fax

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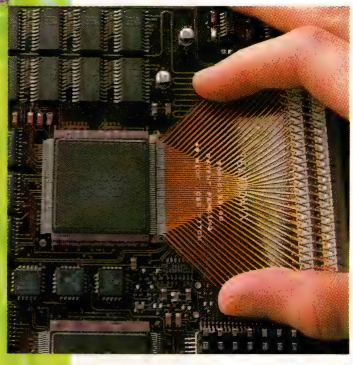

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REWRITABLE DATA-STORAGE

machines, printers, personal digital assistants, and interactive and imaging applications.

The benefits of disk rewritability and portability are beginning to catch on with consumers. Since the debut of MiniDisc technology a couple of years ago, Sony has sold more than 400,000 MiniDisc players worldwide. If MiniDisc-player cloning by Aiwa, Sanyo, and Sharp parallels MDH-10's spread in business applications, Sony can look to portable data-storage and -retrieval as a market that's rife with potential. MiniDisc's rewritability and size will remain among its biggest selling points for high- and low-tech consumers alike. EDN

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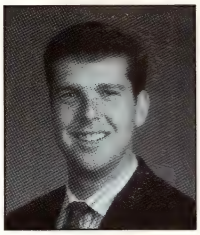

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1970s TECHNOLOGY POSITIONS MINIDISC FOR 21ST-CENTURY APPLICATIONS

When Sony introduced its music MiniDisc to the consumer market a couple of years ago, audiophiles were less than awed by Sony's technological "breakthrough." Partly to blame was Sony's touting of 20-year-old technology as MiniDisc's claim to fame.

MiniDisc's development stretches back into the late 1970s, when Sony R&D began developing an optical-disk product for recording and rerecording. By 1988, the company had introduced a rewritable magneto-optical disk for computer data storage. Finally, in 1992, MiniDisc made its debut, following the birth of the CD by about 10 years.

To design MiniDisc, Sony combined a variety of older, readily available technologies and manufactured the device using modified CD-production techniques. For a variety of reasons, including initial product cost and the media's lukewarm reception to MiniDisc as a revolution in audio technology, consumer demand has been slow to grow.

Sony released two versions of MiniDisc: playback-only, geared to the music industry, and recordable, for high-tech and computer data-storage and -retrieval applications.

A MiniDisc measures 64 mm in diameter, which is approximately half the size of CDs. Similar to the length of a standard CD, MiniDisc handles 74-minute playback. But MiniDisc stores this amount of data using recording techniques technically different from those of CDs.

To record and rerecord data, MiniDisc depends on magnetic-field-modulation technology. Magnetic-field-modulation overwriting uses a laser on one side of the disk to apply heat to a specific location and "loosen" old data on the opposite side. A new magnetic field then maps to that assigned location. Because a magnetic recording head and laser work simultaneously on opposite sides of MiniDisc, the disk's shutter opens on both sides.

MiniDisc's shock-proof solid-state design suits it for portable handheld applications. A MiniDisc player uses semiconductor memory as a shock buffer. Its 1-Mbit memory holds an amount of data equivalent to 3 sec of playing time before sending the data for D/A conversion. If the pickup loses its position, or if an interruption in data flow occurs, semiconductor memory flows data back at a 0.3-Mbps rate. Once the laser resumes its original position, it reads data from the disk at 1.4 Mbps, replenishing the memory in less than 1 sec.

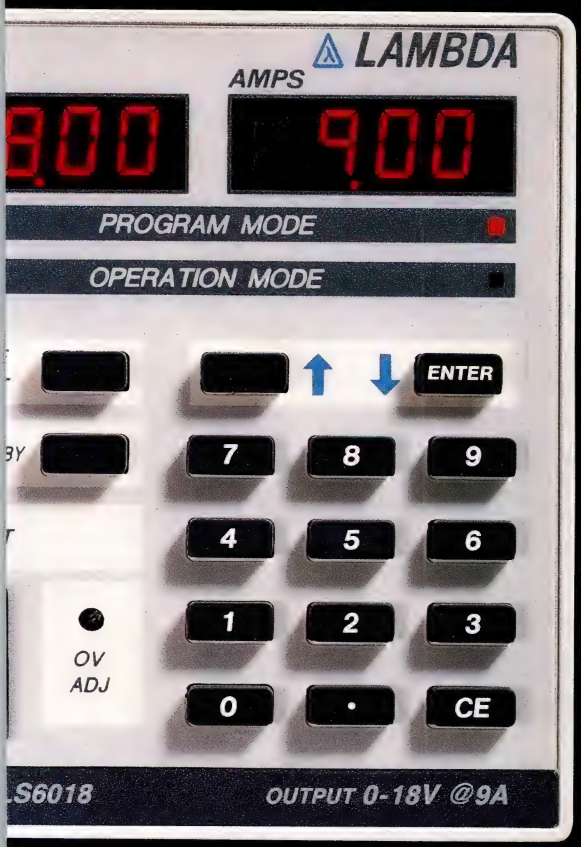
To fit MiniDisc's digital data into its compact size, designers turned to a data-compression technique called adaptive transform acoustic coding (ATRAC). ATRAC enables MiniDisc to read data at 1.4 Mbps; because playback takes only 0.3 Mbps, MiniDiscs deliver digital sound reproduction using one-fifth the amount of data previously required.

ATRAC is essential to MiniDisc sound integrity. Music that records digitally on a MiniDisc differs slightly from read-only music on a CD. This difference is due to increased levels of quantization noise resulting from MiniDisc's size.

ATRAC successfully adapts audio signals to a human ear's sensitivity to varying frequencies. Because the human ear is most sensitive to frequencies near 4 kHz and less sensitive at higher frequencies, a 4-kHz tone audible at one power level may be inaudible at the same power level, but at a different frequency. Similarly, quantization noise may be audible at one frequency and inaudible at another.

ATRAC adapts audio signals to the ear's changing sensitivity by hiding quantization noise in frequency regions where high signal levels correspond to musical activity. When music records on a MiniDisc, ATRAC analyzes the music signal and determines frequency-region sensitivity. ATRAC ensures that sensitive regions are recorded accurately and sacrifices accuracy in other regions, where the ear is less sensitive. Based on this principle, ATRAC renders MiniDisc quantization noise inaudible, ensuring that sound quality matches that of a CD. In addition, ATRAC features nonuniform time-splitting, allowing analysis of 1.45- or 2.9-msec blocks of time to keep up with rapidly changing or vivid music passages.

MiniDisc's modulation system converts 8-bit encoded signals into 14-bit signals to match digital signals to disk transmission characteristics. It uses Reed-Solomon Code for error correction. ATRAC-reduced audio data group into blocks for recording in a format similar to the CD-ROM mode 2 standard.



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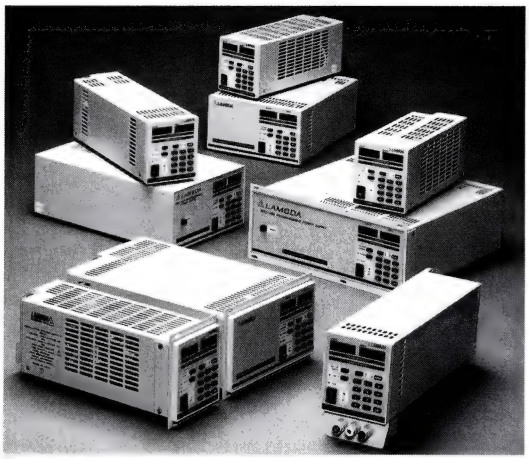

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Complete Selection	Lambda's LL Series Lab Line has 59 standard models up to 800W, up to 300V, up to 100A.
User Selectable 110/220VAC Input Range	Easily adaptable for operation anywhere in the world.
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OUTPUT	MAX CURRENT (AMPS) AT AMBIENT TEMPERATURE OF 40°C	50°C	60°C	71°C	UNIT PRICE PER DELIVERED QUANTITY 1	10	25	MODEL
0-8V	3.50	2.90	1.75	–	$ 684	$ 622	$ 611	**LLS-3008**
	5.00	4.30	3.20	–	749	679	657	**LLS-4008**
	10.00	7.90	6.30	–	849	769	748	**LLS-5008**
	20.00	20.00	16.50	13.50	1030	933	905	**LLS-6008**
	35.00	35.00	30.00	25.00	1211	1098	1060	**LLS-7008**
	50.00	47.00	41.00	33.70	1373	1245	1202	**LLS-8008**
	100.00	90.00	78.00	57.00	1723	1562	1517	**LLS-9008**
0-18V	1.60	1.30	0.80	–	684	622	611	**LLS-3018**
	2.40	2.10	1.50	–	749	679	657	**LLS-4018**
	4.50	3.50	2.80	–	849	769	748	**LLS-5018**
	9.00	9.00	8.20	6.60	1030	933	905	**LLS-6018**
	16.00	16.00	13.50	11.00	1211	1098	1060	**LLS-7018**
	24.00	22.20	20.50	18.00	1373	1245	1202	**LLS-8018**
	45.00	40.00	33.00	25.00	1723	1562	1517	**LLS-9018**
0-40V	0.70	0.60	0.35	–	684	622	611	**LLS-3040**
	1.00	1.00	0.85	–	749	679	657	**LLS-4040**
	2.00	1.60	1.30	–	849	769	748	**LLS-5040**
	4.00	4.00	3.80	3.10	1030	933	905	**LLS-6040**
	7.00	7.00	6.00	5.00	1211	1098	1060	**LLS-7040**
	10.00	9.80	9.20	8.00	1373	1245	1202	**LLS-8040**
	20.00	18.00	15.00	11.00	1723	1562	1517	**LLS-9040**
0-60V	0.50	0.42	0.25	–	684	622	611	**LLS-3060**
	0.70	0.70	0.60	–	749	679	657	**LLS-4060**
	1.40	1.10	0.90	–	849	769	748	**LLS-5060**
	2.80	2.80	2.60	2.10	1030	933	905	**LLS-6060**
	4.80	4.80	4.10	3.40	1211	1098	1060	**LLS-7060**
	7.00	6.60	6.10	5.30	1373	1245	1202	**LLS-8060**
	14.00	12.00	10.00	8.00	1723	1562	1517	**LLS-9060**
0-120V	0.25	0.21	0.13	–	684	622	611	**LLS-3120**
	0.36	0.36	0.30	–	749	679	657	**LLS-4120**
	0.70	0.55	0.45	–	849	769	748	**LLS-5120**
	1.40	1.40	1.30	1.00	1030	933	905	**LLS-6120**
	2.40	2.40	2.10	1.70	1211	1098	1060	**LLS-7120**
	3.50	3.40	3.20	2.70	1373	1245	1202	**LLS-8120**
	7.00	6.00	5.00	4.00	1723	1562	1517	**LLS-9120**
0-300V	0.14	0.12	0.11	–	862	780	754	**LLS-4300**
	0.28	0.22	0.18	–	974	881	856	**LLS-5300**
	0.56	0.56	0.52	0.40	1277	1154	1087	**LLS-6300**
	2.80	2.40	2.00	1.60	2239	2025	1966	**LLS-9300**

Note: Maximum output current applies over the entire output voltage range.

LLS-GPIB Series IEEE-488 Programmable Power Supplies

OUTPUT	MAX CURRENT (AMPS) AT AMBIENT TEMPERATURE OF 40°C	50°C	60°C	UNIT PRICE PER DELIVERED QUANTITY 1	10	25	MODEL
0-8V	3.50	2.90	1.75	$2495	$2269	$2155	**LLS-3008-GPIB**
	20.00	20.00	16.50	2716	2471	2347	**LLS-6008-GPIB**
	50.00	47.00	41.00	3159	2874	2731	**LLS-8008-GPIB**
	100.00	90.00	78.00	3547	3227	3065	**LLS-9008-GPIB**
0-18V	1.60	1.30	0.80	2495	2269	2155	**LLS-3018-GPIB**
	9.00	9.00	8.20	2716	2471	2347	**LLS-6018-GPIB**
	24.00	22.20	20.50	3159	2874	2731	**LLS-8018-GPIB**
	45.00	40.00	33.00	3547	3227	3065	**LLS-9018-GPIB**
0-40V	0.70	0.60	0.35	2495	2269	2155	**LLS-3040-GPIB**
	4.00	4.00	3.80	2716	2471	2347	**LLS-6040-GPIB**
	10.00	9.80	9.20	3159	2874	2731	**LLS-8040-GPIB**
	20.00	18.00	15.00	3547	3227	3065	**LLS-9040-GPIB**
0-60V	0.50	0.42	0.25	2495	2269	2155	**LLS-3060-GPIB**
	1.40	2.80	2.60	2716	2471	2347	**LLS-6060-GPIB**
	7.00	6.60	6.10	3159	2874	2731	**LLS-8060-GPIB**
	14.00	12.00	10.00	3547	3227	3065	**LLS-9060-GPIB**
0-120V	0.25	0.21	0.13	2495	2269	2155	**LLS-3120-GPIB**
	1.40	1.40	1.30	2716	2471	2347	**LLS-6120-GPIB**
	3.50	3.40	3.20	3159	2874	2731	**LLS-8120-GPIB**
	7.00	6.00	5.00	3547	3227	3065	**LLS-9120-GPIB**

Note: Maximum output current applies over the entire output voltage range.

Accessories

	KIT #	COLOR	PRICE	MODEL
Rack Mount Kits for LRA-17 Rack Adapter	KT-53	–	$65.00	LLS-3000-GPIB, 6000-GPIB
	KT-54	–	85.00	LLS-8000-GPIB, 9000-GPIB
Rack Mount Kits for LRA-20 Rack Adapter	KT-44	Off-white	40.00	LLS-3000, 4000, 5000, 6000, 7000
	KT-45	Brown	40.00	LLS-3000, 4000, 5000, 6000, 7000
	KT-51	Off-white	65.00	LLS-8000, 9000
	KT-45	Brown	65.00	LLS-8000, 9000
Benchtop Front Panel Jack Kits*	KT-46	–	65.00	LLS-3000
	KT-47	–	65.00	LLS-4000
	KT-48	–	65.00	LLS-5000
	KT-49	–	65.00	LLS-6000
	KT-50	–	65.00	LLS-7000

	DIMENSIONS (INCHES)	PRICE	MODEL
Rack Adapters	5.19 x 19.0 x 21.0	$325.00	LRA-17
	5.19 x 19.0 x 16.5	286.00	LRA-20

	FOR USE WITH RACK ADAPTERS	PANEL WIDTH	PRICE	MODEL
Blank Front Panels	LRA-17, 20	¼ Rack	$46.00	LBP-12
	LRA-17, 20	½ Rack	84.00	LBP-14

*When using the bench mount accessory, the outputs are taken from banana jacks located at the front of the power supply for the LLS-3000 through LLS-7000 Series.

LLS Series Specifications

AC Input

line.....85 to 132VAC or 170 to 265VAC, user selectable 47-440 Hz.

Input Power

Model	Efficiency (Min. @ Max. P_{out})	Current (RMS Max.)	Power (Max.)
LLS-3000	45%	1.2A	62W
LLS-4008, 4018	50%	1.5A	87W
LLS-4040, 4060, 4120, 4300	55%	1.5A	87W
LLS-5008, 5018	60%	2.7A	135W
LLS-5040, 5060, 5120, 5300	65%	2.7A	135W
LLS-6008, 6018, 6040, 6060, 6120, 6300	65%	4.2A	245W
LLS-7040, 7060, 7120	75%	7.5A	450W
LLS-8008, 8018	68%	10.0A	620W
LLS-8040, 8060, 8120	73%	10.0A	620W
LLS-9008	72.5%	17.5A	1100W
LLS-9018, 9040	75%	17.5A	1100W
LLS-9060, 9120, 9300	77.5%	17.5A	1100W

DC Output

Voltage range shown in table.

Regulated Voltage (Constant)

line regulation .....0.05% for line variations from 85 to 132VAC or 170 to 265VAC, 0.01% + 1mV for LLS-3000.

load regulation .....0.05% for load variations from 0 to full load. 0.01% + 1mV on LLS-3000 Series.

remote programming resistance.....Customer adjustable from 200Ω/Volt to 1000Ω/Volt, 200Ω/Volt on LLS-3008, LLS-3060, 400Ω/Volt on LLS-3120, 1000Ω/Volt on LLS-4300, LLS-5300, LLS-6300 and LLS-9300.

remote programming voltage.....Volt per volt or 0-5V signal using an isolated voltage source for zero to full voltage out, customer selectable.

ripple and noise (20MHz Bandwidth)....5mV RMS, 35mV pk-pk on 8V and 18V models. 10mV RMS, 75mV pk-pk on 40V and 60V models. 20mV RMS, 150mV pk-pk on 120V models and LLS-6300, LLS-9300. 1mV RMS, 5mV pk-pk on all LLS-3000 models, 35mV RMS, 300mV pk-pk on LLS-4300 and LLS-5300.

temperature coefficient.....0.03%/°C. 0.01%/°C on LLS-3000 Series

Thermal Protection

Internal temperature sensing circuit protects unit from excessive ambient temperature on the LLS-3000, 4000, 5000 and 7000 Series. The LLS-6000, 8000 and 9000 Series are protected from inadequate air velocity by an internal air flow sensing circuit. A front panel LED indicator will light upon shutdown. AC power must be recycled.

Overcurrent Protection

Adjustable, automatic self-resetting electronic current limiting is included.

Overvoltage Protection

Adjustable overvoltage protection removes the inverter drive in the event of an OV condition. AC power must be recycled in order to restore operation.

Constant Current

(Current regulated line and load) Automatic Crossover.

current range.....5% to full load current. 1% on all LLS-3000 models

line regulation .....0.3% of Io (max) for line variations from 85 to 132VAC or 170 to 265VAC, 2.5mA or 1% (whichever is greater) on LLS-3000. 2.5mA or 0.3% (whichever is greater) on LLS-4000 models 2.5mA on LLS-5300.

load regulation .....0.3% of Io (max) for load variations from short circuit to rated DC voltage 2.5mA or 1% (whichever is greater) on LLS-3000 models. 2.5mA or 0.3% (whichever is greater) on LLS-4000 models 2.5mA on LLS-5300.

remote programming current.....0-5V isolated signal for zero to Io (max).

current ripple .....1.0% Io (max) RMS.

In-Rush Current Limiting

Limits in-rush current at turn-on to 20A when connected for 110VAC input and 40A when connected for 220VAC input. 90A on LLS-3000 Series, 30A on LLS-7000.

Remote Sensing

Provision is made for remote sensing to eliminate effect of power output lead resistance on DC regulation.

Remote On/Off

A TTL compatible isolated source or contact closure low voltage or short enables the unit. A TTL compatible high voltage or open circuit turns the unit off.

Operating Temperature Range

Continuous duty from 0°C to +71°C with appropriate derating from +40°C to +71°C (0-60°C for LLS-3000, 4000, 5000 Series).

Storage Temperature Range

–55°C to +85°C.

Cooling

The LLS-3000, 4000 and 5000 Series are convection cooled. The LLS-6000, 7000, 8000 and 9000 Series are fan cooled. Leave adequate clearance at all air intakes and exhausts.

DC Output Controls

Output voltage and output current adjust is via a front panel key pad.

AC Power Control

On-off switch on front panel of all units.

Input and Output Connections

Input is via an IEC power line connector. DC output is via heavy duty, PC board mounted barrier strips (threaded bus bars on LLS-8000, 8018, 9008 and 9018 units).

Meters

Digital 3.5 digit voltage meter and 3 digit current meter on front panel. 3 digit voltage meter and 2 digit current meter on LLS-4300 and LLS-5300.

LED Status Indicator

CV/CC indicator, overvoltage/overtemperature indicator and standby LED indicators on front panel.

Physical Data

Package Model	Weight Lbs. Net	Weight Lbs. Ship	Dimensions (inches)
LLS-3000	7.00	8.00	4.28 x 3.81 x 10.00
LLS-4000	5.00	6.00	4.28 x 3.81 x 11.00
LLS-5000	7.00	8.00	4.28 x 3.81 x 12.00
LLS-6000	7.25	8.00	4.28 x 3.81 x 13.00
LLS-7000	8.56	9.31	4.28 x 3.81 x 15.00
LLS-8000	12.20	16.70	4.28 x 8.00 x 10.50
LLS-9000	14.50	19.00	4.28 x 8.00 x 12.88

Guaranteed For 3 Years

Three year guarantee includes labor as well as parts. Guarantee applies to operation at full published specifications at the end of three years.

LLS-GPIB Series Specifications

AC Input

line.....85 to 132VAC or 170 to 265VAC, user selectable 47-440 Hz.

Input Power

Model	Efficiency (Min. @ Max. P_{out})	Current (RMS Max.)	Power (Max.)
LLS-3000-GPIB	36%	1.6A	78W
LLS-6000-GPIB	65%	4.0A	245W
LLS-8008-GPIB, 8018-GPIB	68%	10.0A	620W
LLS-8040-GPIB, 8060-GPIB, 8120-GPIB	73%	10.0A	620W
LLS-9008-GPIB	72.5%	17.5A	1100W
LLS-9018-GPIB, 9040-GPIB	75%	17.5A	1100W
LLS-9060-GPIB, 9120-GPIB	77.5%	17.5A	1100W

DC Output

Voltage range shown in table.

Regulated Voltage (Constant)

line regulation .....0.05% for line variations from 85 to 132VAC or 170 to 265VAC. 0.01% + 1mV for LLS-3000-GPIB models.

load regulation .....0.05% for load variations from 0 to full load. 0.01% + 1mV on LLS-3000-GPIB Series.

remote programming voltage.....Volt per volt or 0-5V signal using an isolated voltage source for zero to full voltage out, customer selectable.

ripple and noise.....5mV RMS, 35mV pk-pk on 8V and 18V models. 10mV RMS, 75mV pk-pk on 40V and 60V models. 20mV RMS, 150mV pk-pk on 120V models.

temperature coefficient.....0.04%/°C.

Constant Current

(Current regulated line and load) Automatic Crossover

current range.....5% to full load current. 1% on LLS-3000-GPIB.

line regulation .....0.3% of Io (max) for line variations from 85 to 132VAC or 170 to 265VAC, 2.5mA or 1% (whichever is greater) on LLS-3000-GPIB.

load regulation .....0.3% of Io (max) for load variations from short circuit to rated DC voltage 2.5mA or 1% (whichever is greater) on LLS-3000-GPIB.

remote programming current.....0-5V isolated signal for zero to Io (max).

current ripple .....1% Io (max) RMS.

Thermal Protection

Internal temperature sensing circuit protects the unit from excessive ambient temperature on the LLS-3000-GPIB. The LLS-6000-GPIB, 8000-GPIB and 9000-GPIB are protected from inadequate air velocity by an internal air flow sensing circuit. A front panel LED will light upon shutdown. AC power must be recycled.

Overvoltage Protection

Adjustable overvoltage protection removes the inverter drive in the event of an OV condition. AC power must be recycled in order to restore operation.

IEEE-Based DC Out of Tolerance

The host controller will be notified in the event that the DC exceeds user-defined windows around voltage and current programmed values.

Overcurrent Protection

Adjustable, automatic electronic current limiting is included.

IEEE-Based DC Fault Monitoring

The system response to detected faults is as follows:

Fault	Response
DC out of user set tolerance	SRQ interrupt activated
Overvoltage value exceeded	Reset initiated and SRQ interrupt activated
Current limit exceeded	Reset initiated and SRQ interrupt activated

IEEE Programming

(as a percentage of full scale values)

	Voltage	Current
Resolution	0.025%	1.0%
Accuracy	0.10%	2.0%
Programming Range	0.00%-99.99%	1.0%-99%

IEEE Metering

Voltage metering accuracy is ±0.7% of full scale. Current metering accuracy is ±1.7% of full scale +20mA.

In-Rush Current Limiting

Limits in-rush current at turn-on to 20A when connected for 110VAC input and 40A when connected for 220VAC input. 90A on LLS-3000-GPIB.

Remote Sensing

Provision is made for remote sensing to eliminate effect of power output lead resistance on DC regulation.

Remote On/Off

A TTL compatible isolated source or contact closure low voltage or short enables the unit. A TTL compatible high voltage or open circuit turns the unit off.

Operating Temperature Range

Continuous duty from 0°C to +60°C with appropriate derating (see tables).

Storage Temperature Range

–55°C to +85°C.

Cooling

The LLS-3000-GPIB is convection cooled. The LLS-6000-GPIB, LLS-8000-GPIB and LLS-9000-GPIB are fan cooled. Leave adequate clearance of all air intakes and exhausts.

DC Output Controls in Manual Mode

Output voltage and output current adjust is via a front panel keypad when the front panel auto/manual mode button is in the manual position.

AC Power Control

On-off switch on front panel of all units.

Input and Output Connections

Input is via an IEC power line connector (barrier strip on LLS-9000-GPIB). DC output is via heavy duty, PC board mounted barrier strips (threaded bus bars on LLS-8000-GPIB, LLS-8018-GPIB, LLS-9008-GPIB and LLS-9018-GPIB). IEEE bus connection is through standard D connector.

Front Panel Meters

Digital 3.5 digit voltage and 3 digit current meter on front panel.

LED Status Indicators

Manual mode indicator, CV/CC indicator, overvoltage/over-temperature indicator and standby LED indicators on front panel.

Physical Data

Package Model	Weight Lbs. Net	Weight Lbs. Ship	Dimensions (inches)
LLS-3000-GPIB	11.5	14.0	8.00 x 4.28 x 13.88
LLS-6000-GPIB	11.9	14.0	8.00 x 4.28 x 13.31
LLS-8000-GPIB	17.2	19.0	12.28 x 4.28 x 12.69
LLS-9000-GPIB	19.3	23.0	12.28 x 4.28 x 12.81

Guaranteed For 3 Years

Three year guarantee includes labor as well as parts. Guarantee applies to operation at full published specifications at the end of three years.

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Spread-spectrum communication rises from military roots to star in wireless world

DAN STRASSBERG, SENIOR TECHNICAL EDITOR

From high data security to effective spectrum use to improved noise immunity, spread spectrum offers it all. But these virtues, though inherent in the technology, don't come automatically or easily to real systems.

The lack of security in cordless telephones (the kind you might have in your home—not mobile cellular phones) is legendary. Perhaps you have even picked up a neighbor's conversation on your cordless phone and wondered whether your neighbor could eavesdrop on you. Imagine what would happen if you worked in a large organization—a hospital, for example—that had decided to use cordless phones extensively. The idea of using such phones instead of the beepers that physicians and other hospital personnel use so routinely seems attractive. But it quickly loses its appeal when you realize that, with so many cordless phones in a small area, others would be all too likely to listen in on your conversations.

That's where SpectraLink Corp comes in. It builds the Pocket Communications System (PCS) for facilities whose personnel need to stay in touch with one another, even though they are constantly on the go throughout a limited area. With PCS, a facility can enhance its private branch exchange (PBX) or Centrex system in a way that allows users to access all system features from pocket-sized cordless phones powered by rechargeable batteries. The technology that makes PCS possible is spread-spectrum communication. Thanks to spread spectrum, large numbers of PCS users can operate their cordless phones simultaneously with uncompromised security and without interfering with one another.

Not much bigger than beepers that offer much more limited capabilities, the 6-oz battery-powered phones used by SpectraLink Corp's PCS provide full access to all features of a PBX or Centrex system.

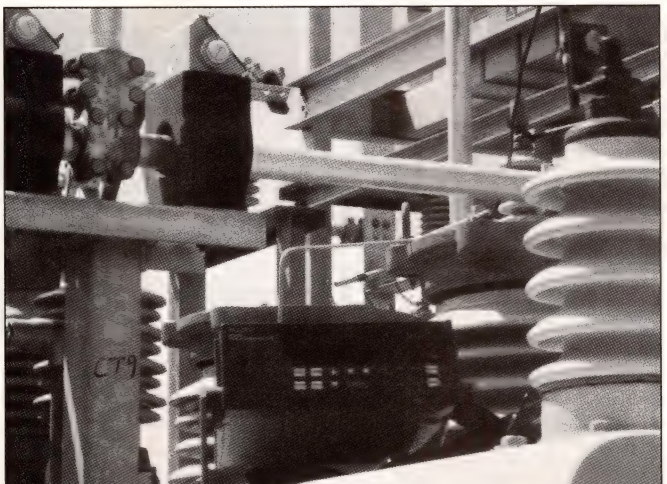
Spread spectrum is indeed a marvelous technology. Cloaked in secrecy for many years because of its origins in high-security military systems, it is finding new celebrity as the rising star of wireless communications.

SpectraLink's cordless phones do not require FCC licensing for two reasons: The transmitters use low

SPREAD-SPECTRUM COMMUNICATION

power, and the system operates in a 902- to 928-MHz band. The FCC designates this band for unlicensed, low-power industrial, scientific, and medical (ISM) use. Transmissions in the ISM bands use spread-spectrum techniques, and, as a consequence, multiple signals can be present in the same frequency band at the same time without interfering with each other. Moreover, the system offers greater immunity to noise than do cordless phones that use narrowband technology.

Industry observers, even in the nontechnical press, have widely touted spread spectrum's signal/noise and data-security advantages. In fact, the enthusiasm of nontechnical journalists is running so high that it may be positioning the technique for a fall. Those who have embraced spread spectrum without becoming familiar with its exquisite complexity and arcane nuances should remember the old adage about claims that sound "too good to be true": Even if much of the hype surrounding spread spectrum isn't downright false, it is misleading.



This wireless data logger from Fluke Corp operates reliably in dangerous and noisy industrial environments, thanks to a tiny, direct-sequence, spread-spectrum modem from Proxim.

Advantages not automatic

Yes, spread spectrum inherently provides high data security. But not all implementations take advantage of this feature. Yes, spread spectrum can provide excellent noise immunity. But blindly applying the technology fails to guarantee S/N ratios better than those of narrowband communication systems; incorrectly applied, spread spectrum can even cause inferior noise performance.

Compared with narrowband communications, spread spectrum promises vastly more efficient spectrum use. But phasing spread spectrum into the existing cellular network poses gargantuan problems. The equally unattractive alternatives are irreconcilable spectrum-allocation conflicts or the instant obsolescence of billions of dollars' worth of equipment in the hands of the public and cellular-service providers.

Spread spectrum is difficult to understand. That factor is one of the most potent militating against the technology's rapid takeover of wireless voice and data communication. Deciding whether narrowband or spread-spectrum communication is best for an application requires a host of complex trade-offs. These trade-offs involve such factors as the nature of the information—for example, is it voice or data? In data communication, the delays introduced by error-correcting protocols are usually not serious. However, similar delays become unacceptable in two-way voice communication—even when the voice is encoded in digital form.

The nature of the interfering signals is another factor that affects spread-spectrum's suitability and determines whether an application should use direct sequence or frequency hopping (spread spectrum's two main forms). Although spread-spectrum communications might seem to be immune to narrowband interference, such interference can be devastating. A frequency-hopping system that hops to a frequency occupied by a narrowband signal can lose all data until its next hop. But if the hops occur often enough and are of short-enough duration, the loss of information may be acceptable.

Analyzing an application often involves not only solving complicated math, but also finding guidance. So-called spread-spectrum experts often disagree. In some quarters, the deba over the superiority of direct sequen vs frequency hopping has assumed t dimensions of a religious war. Dispa sionate experts—when you can fi them—often refuse to make blank recommendations about technic choices. Moreover, don't be surprised some experts won't even spell out t factors you should consider in reachi a decision. The most-uttered phrase discussions of spread-spe trum communications is, depends."

Spread spectrum owes surge in popularity not or to its unique attributes b also to modern semicondu tor technology. Even fi years ago, implementing spread-spectrum receiver a consumer application w not economically feasib But higher levels of integ tion have driven down t size and cost of the hardwa to the point where handh spread-spectrum cellu phones are both technica and economically practic

Of the two basic sprea spectrum technologies—frequen hopping and direct sequence—f quency hopping is the easier to und stand. In frequency hopping, the inf mation is modulated onto a carr derived from a frequency synthesizer pseudorandom sequence (PRS) det mines the synthesizer's output f quency.

The carrier is restricted to a finite of predetermined frequencies, all which must be used for roughly eq portions of the time. In the 902- to 9 MHz ISM band, a frequency-hoppi transmitter must use at least 50 f quencies. In the higher frequency I bands, a transmitter must use at least frequencies. In the lower ISM band transmitter must occupy a single f quency for no more than 0.4 sec in a sec interval. In the higher bands transmitter must occupy a single f quency for no more than 0.4 sec in a sec interval.

Nothing in the FCC's rules dicta that a transmitter shall dwell conti ously at a single frequency for as long 0.4 sec, however. Indeed, the 0.4 that a transmitter spends at a frequ

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cy over the course of 20 or 30 sec usually consists of many hops to that frequency. In any system, the duration of all hops is constant.

The receiver for the frequency-hopping transmissions must be synchronized with the transmitter. Like the transmitter frequency, the receiver frequency is under the control of a synthesizer. The same PRS drives both synthesizers.

The PRS is at the heart of the data security inherent in frequency hopping. Because a sequence can allow multiple hops to each frequency, a system that uses 50 frequencies can hop many more than 50 times during a single repetition of a sequence. Because of the length of the sequence and the large number of possible next frequencies at each hop, the number of possible sequences is enormous. Thus, it is unlikely that, without "inside information," someone could set up a receiver to track a frequency-hopping transmitter.

The system's noise advantages are the result of its use of a frequency band much wider than that required to transmit the information. Narrowband noise may corrupt the signal for short periods, but in voice transmissions, those periods tend to be so short that they do not affect intelligibility. Similarly, in data transmission, although occasional packets may be corrupted, error-correction schemes generally allow recovery of the data without significantly reducing the data rate.

You might think that using a wide frequency band wastes spectrum space. It doesn't, however, because several frequency-hopping systems can occupy the same frequency band simultaneously without significantly interfering with each other. In this situation, although multiple transmitters sometimes hop to the same frequency at the same time and, therefore, briefly interfere, the interference is slight if the number of transmitters is not excessive.

Simple, elegant, unfathomable

The direct-sequence approach is at once simpler, more elegant, and harder to understand than frequency hopping. Even though the system is simpler and more elegant, it isn't necessarily better or worse. Like frequency hopping, direct sequence uses a PRS. Unlike frequency hopping, it does not use frequency synthesizers. In contrast with frequency hopping, direct-sequence combines the (binary) data with a pseudorandom binary signal in an exclusive-OR gate ahead of the modulator. The highest frequency present in the PRS (the so-called chipping rate) is at least as high as the highest frequency in the data and is usually considerably higher.

The result of combining the data with the PRS is that the bandwidth of the signal that modulates the carrier is much greater than it otherwise would be; the modulated carrier covers a much greater range of frequencies; and less energy is present at any frequency than would be present without use of the PRS. The total energy contained in the modulated carrier is unaffected by combining the data with the PRS, however.

To recover the original signal, the down-converted receiver output passes through a correlator. The same PRS that was X-ORed with the original data also feeds into this correlator. Other direct-sequence signals are uncorrelated with this PRS, making it possible to recover the original data. Indeed, just as with frequency hopping, multiple direct-sequence signals can occupy the same frequency band simultaneously without interfering with each other. Moreover, the system rejects noise because the correlator behaves, in a sense, like a sharply tuned filter that rejects noise uncorrelated with the PRS. Neither narrowband nor truly random noise correlates with a PRS.

Although the use of frequency synthesizers might make frequency-hopping systems more expensive than direct-sequence systems, general agreement on this point is lacking. Furthermore, frequency-hopping transmitters emit signals that, at any instant, cover only a narrow frequency range. As a result, frequency-hopping systems might be able to use lower transmitter power to achieve S/N ratios equivalent to those of direct-sequence systems. If frequency hopping can provide S/N ratios equivalent to or better than those of direct sequence, frequency hopping could become the technology of choice in battery-powered applications. If you try to determine what direction the technology actually will take, however, the answer you get depends on whom you ask. EDN

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Reference

1. Gallant, John, "Digital Wireless Networks," *EDN*, March 4, 1993, pg 78.

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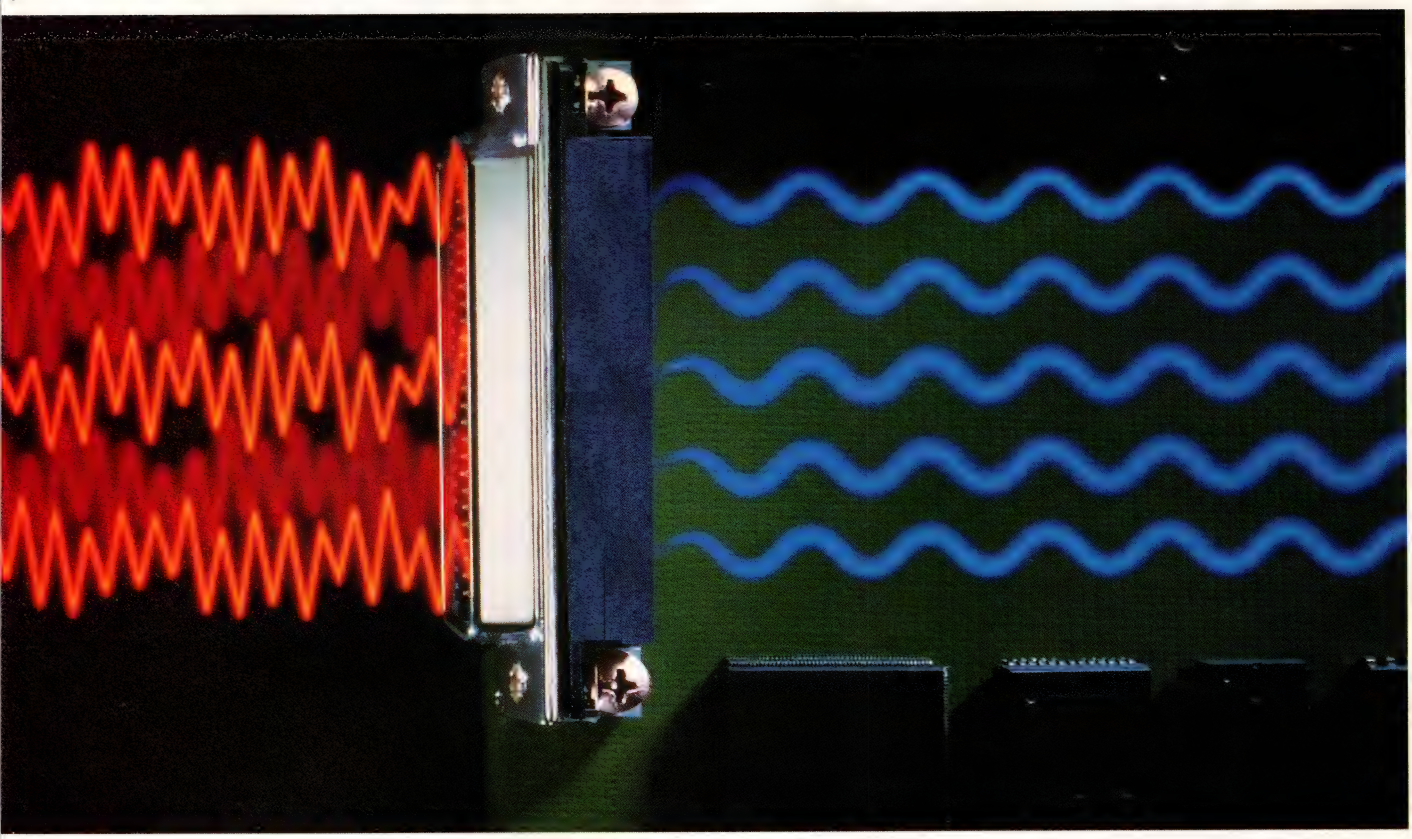

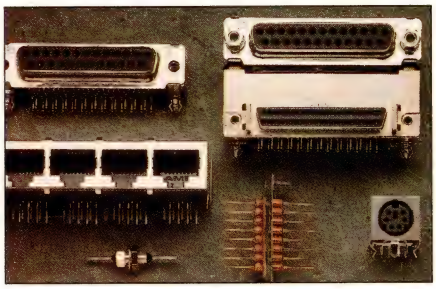

FILTER TYPE	INSERTION LOSS*
Ferrite	3-8 dB
Capacitive Film	10-30 dB
Chip Capacitor	10-40 dB
Capacitive Array on Ferrite	15-40 dB
Tubular Capacitor	20-40 dB
Distributed Element	20-90 dB

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CIRCLE NO. 36

GRAPHICS ACCELERATORS BRING 3-D TO PCs

MANJU NATH, TECHNICAL EDITOR

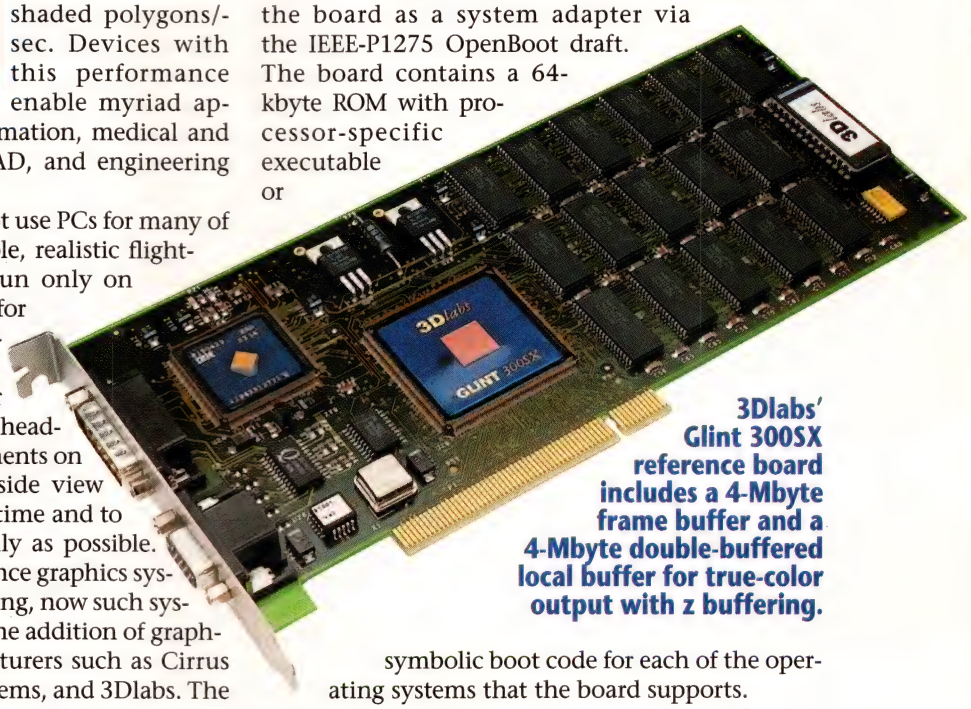
Although 3-D-graphics applications have been around for some time, they have never been plebeian. If you wanted 3-D graphics, you had to use workstations. However, inexpensive 3-D-graphics accelerators that render complex 3-D images are about to transform the desktop PC into a sophisticated workstation. Neil Trevitt, vice president of marketing for 3Dlabs, defines an entry-level workstation as one that can draw 300,000 shaded polygons/-sec. Devices with this performance enable myriad applications: virtual reality, animation, medical and engineering visualization, CAD, and engineering design, to name a few.

Inexpensive 3-D-graphics accelerators can now render complex 3-D images. This low-cost capability will transform desktop PCs into sophisticated workstations.

Until recently, you could not use PCs for many of these applications. For example, realistic flight-simulation software would run only on graphics workstations selling for more than $50,000. The reasons involve the system's performance requirements. For example, a flight simulator's head-up display places two requirements on a system: to update the outside view from a plane's cockpit in real time and to render the scene as realistically as possible. Although only high-performance graphics systems can perform such rendering, now such systems can be PC-based—with the addition of graphics accelerators from manufacturers such as Cirrus Logic, Media Labs, S-MOS Systems, and 3Dlabs. The companies claim their products will bring high-performance, affordable 3-D graphics to PCs. They expect such accelerators to be available on 60% of all PCs by 1997.

One product, the 3DMedia SX, a $2000 plug-in graphics-accelerator card from Media Labs Inc of Houston, promises flight simulation on a PC. The board also suits engineering-visualization and -design, CAD, virtual-reality, and animation applications. As a rasterizer, the board efficiently renders realistic images for animation and simulation applications.

Based on 3Dlabs' Glint 300SX graphics accelerator, the card supports most display resolutions, color depths, and display types. In addition, the card provides high-end graphics features, such as a 24-bit depth buffer; a stencil mask; fast-clear planes; and 32 bits for red, green, blue, and alpha (RGBA) true-color output. (Alpha makes the card suitable for composite-image applications.) Users can employ the board as a system adapter via the IEEE-P1275 OpenBoot draft. The board contains a 64-kbyte ROM with processor-specific executable or symbolic boot code for each of the operating systems that the board supports.



3Dlabs' Glint 300SX reference board includes a 4-Mbyte frame buffer and a 4-Mbyte double-buffered local buffer for true-color output with z buffering.

The device also maintains output-format flexibility. For example, the board, including the video palette, supports any color depth the Glint chip supports. All output resolutions support double buffering. The only limitation to image resolution is the

3-D GRAPHICS

4-Mbyte video memory: Because 1600×1280-pixel resolution requires a 2-Mbyte memory, double buffering requires a 4-Mbyte memory.

The design includes a studio-quality encoder that makes the board suit such applications as manipulating and modifying digital-image data by adding textual information, fog, or special effects for nonlinear video editing. More important, the encoder allows you to store presentations on VHS tape. You can also select NTSC, PAL, or S-video output in square-pixel, CCIR601, 4X, or any custom resolution from a pulldown menu.

Proprietary logic on the system board controls data flow and video formats, allowing interlaced, noninterlaced, stereoscopic, field-sequential RGB and virtual-reality display. Hardware, rather than software, supports these display types, reducing or eliminating software overhead. A frequency synthesizer for graphics applications supports any output frequency or resolution. A proprietary gate array offers line-lock capability for some operating systems. Line-lock lets you open a 3-D graphics window with independent color depth in the VGA display. A fast-clear feature enhances animation.

An analog VGA pass-through on the Media Labs board eliminates the pixel-related restrictions of traditional VGA pass-through implementations. Wil de Bont, president of Media Labs, believes that, as 3-D graphics becomes more important, interest in VGA compatibility will wane. "All new operating systems will support a more general boot sequence, which is not tied to the VGA BIOS," he says. In line with that philosophy, the 3DMedia SX supports such environments as OpenGL, Open Inventor, AutoCAD, Microstation, X-Windows, PEX, OS/2, Windows NT, Windows 3.xx, and Windows95. A proprietary library provides functions that standard application-programming interfaces (APIs), such as OpenGL, don't support.

Chips also do the job

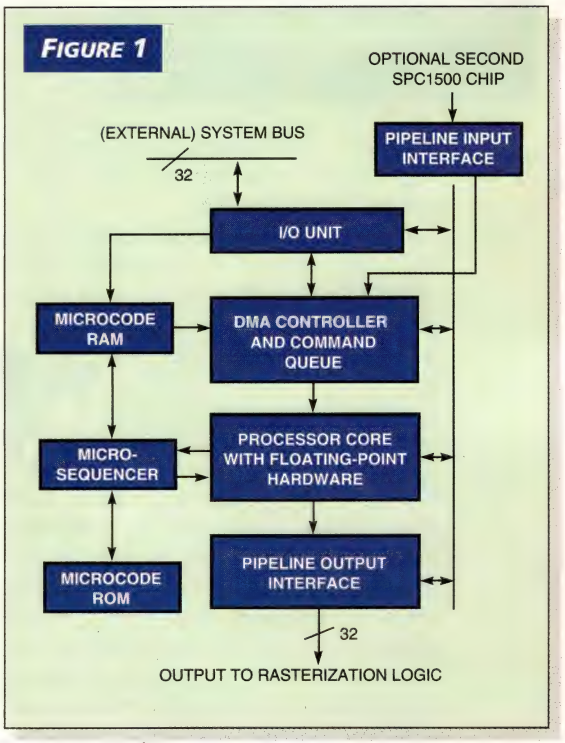
Some manufacturers are taking a chip approach to speeding graphics. For example, Cirrus, S-MOS, and 3Dlabs and have developed ICs that accelerate 3-D graphics. Both Cirrus and 3Dlabs and have devices that do the rendering portion of the 3-D graphics.

You can use the Glint 300SX reference board and Inventor on OpenGL to generate this Gouraud-shaded, z-buffered figure.

Cirrus Logic offers a three-chip graphics accelerator ($150). The set includes a VGA controller and VESA VL-Bus/PCI interface (CL-GD5471), a palette DAC (CL-GD5472), a 2-D graphical user interface, and a 3-D rendering accelerator (CL-GD5470). The CLGD-5470 handles 250,000 shaded, alpha-blended polygons/sec. All the chips are available in 208-pin QFPs.

S-MOS's SPC1500 ($450), a single-chip, 3-D-graphics geometry processor suits point-of-view movement, perspective, clipping, lighting, texture-mapping, and fog-computation applications (**Fig 1**). The product complies with OpenGL and Programmers Hierarchical Interactive Graphics System (PHIGS+) graphics-application-programming languages.

The 223-pin pin-grid array comprises a floating-point/integer ALU, multiply and accumulate units, a DMA processor for data fetches, a microcode ROM, and a RAM cache to store custom instructions. The 33-MHz, asynchronous, DMA-mastering bus has a 32-bit CPU interface. Secondary 32-bit synchronous input and output buses both operate at 50 MHz to move data to and from the rasterization circuitry. The chip lets you implement rasterization with custom circuitry or using the SPC1503 pixel-processor chip. It also lets you easily partition 3-D-related tasks in a graphics environment. The host CPU normally handles the 3-D API, geometry, lighting, and delta calculations. The graphics processor per-



S-MOS's SPC1500, a single-chip, 3D-graphics geometry processor suits point-of-view movement, perspective, clipping, lighting, texture-mapping, and fog-computation applications.

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CIRCLE NO. 38

3-D GRAPHICS

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forms rasterization, Gouraud shading, z buffering, texture mapping, alpha blending, antialiasing, and dithering.

The SPC1500 speeds 3-D-graphics performance, which can be painfully slow, even on high-performance µPs, according to Robert Wong, executive director for graphics and standard products at S-MOS. He claims that adding an SPC1500 to a 60-MHz Pentium-based system speeds the following common 3-D-graphics operations: multiply-and-accumulate operations (about eight times faster than without the chip), transform processing (nearly four times faster), matrix multiplications (five times faster), and xyz-vector-lighting calculations (more than 10 times faster).

3Dlabs' Glint 300SX graphics processor ($150) for rendering operations draws 300,000 shaded, z-buffered, antialiased, translucent polygons/sec and provides 24-bit 2- and 3-D acceleration, an on-chip Peripheral Component Interconnect (PCI) interface, and lookup-table-DAC control.

3Dlabs' Trevitt claims that the Glint API spans a broad spectrum of applications. At one end is CAD-related 3-D graphics using OpenGL, which requires accurate rendering. At the other end of the spectrum are games, which require less accurate geometry calculations, allowing engineers to use short cuts in developing games. Because the product is a single chip, board and system manufacturers can lower the cost and increase the performance of 3-D products for CAD, multimedia, simulation, virtual reality, interactive TV, and games. The company will provide reference board designs, manufacturing kits, and software support in the form of drivers for Win32, X11, and OpenGL, as well as application drivers, such as AutoCAD and Microstation.

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References

1. Glint Hardware Reference Manual, Version 1.5.
2. Glint Programmer's Reference Manual, Version 2.0.
3. Glint Architecture Overview, Version 1.6a.
4. Foley, van Dam, Feiner, and Hughes. *Computer Graphics: Principles and Practice*, Second Edition, Addison-Wesley, November 1992.

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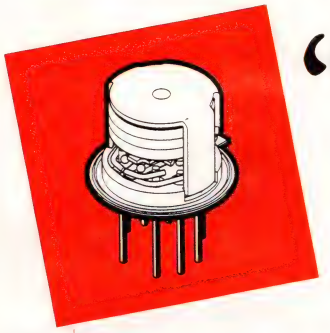

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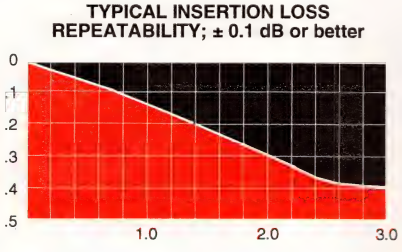

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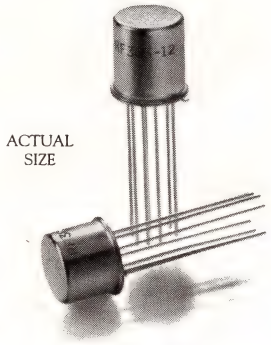

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CIRCLE NO. 78

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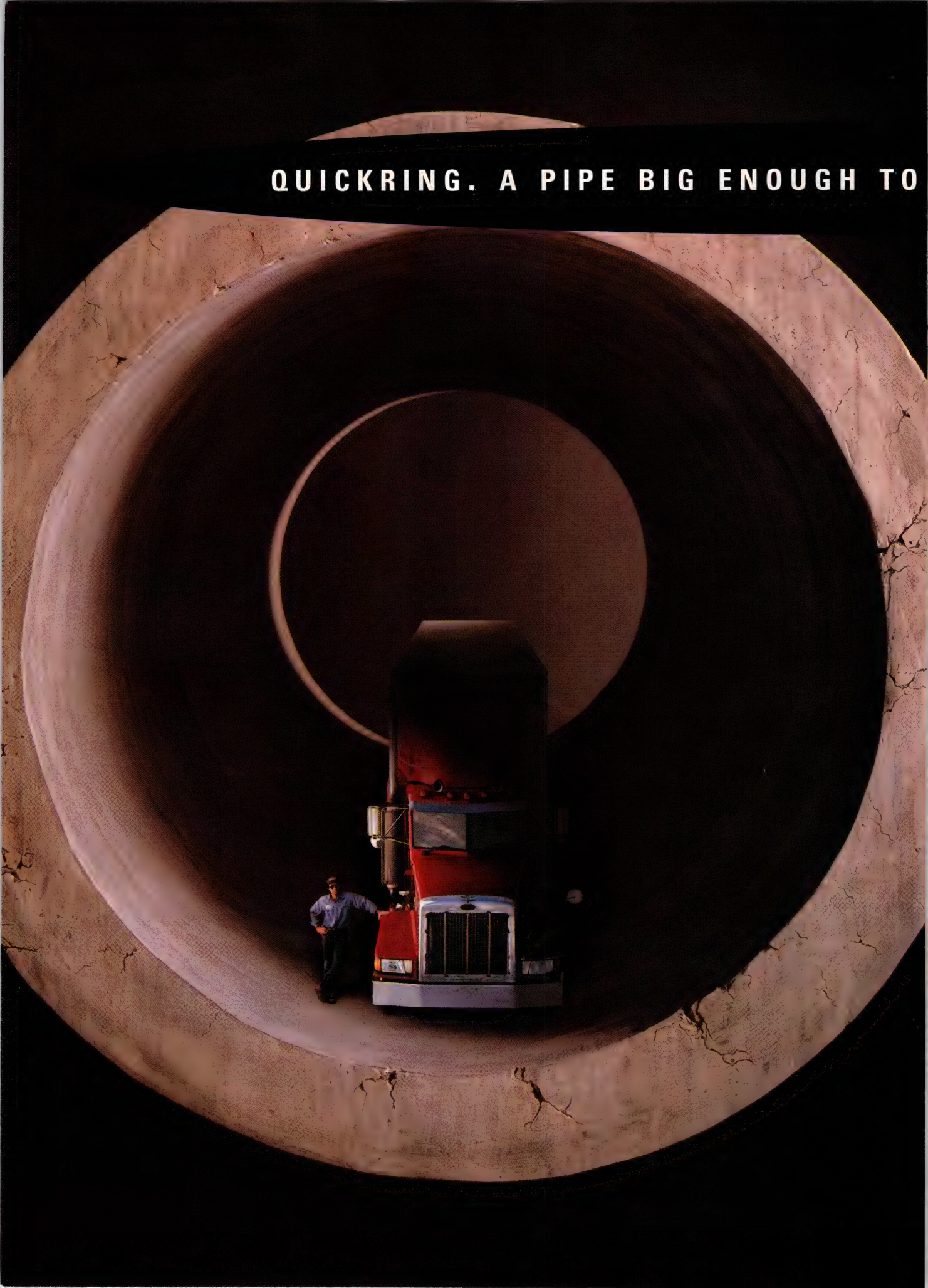

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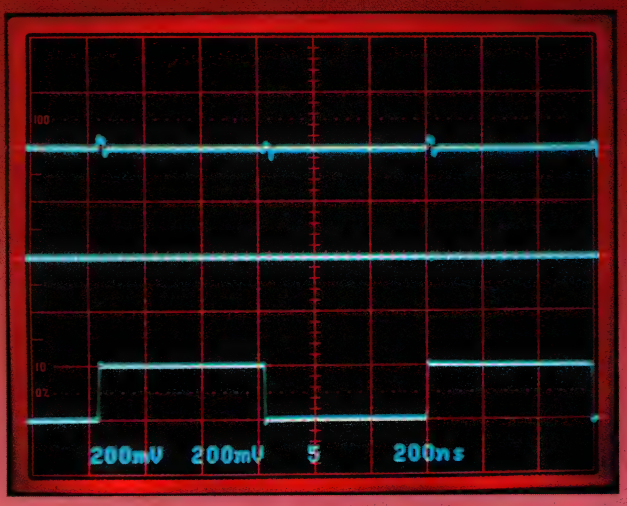
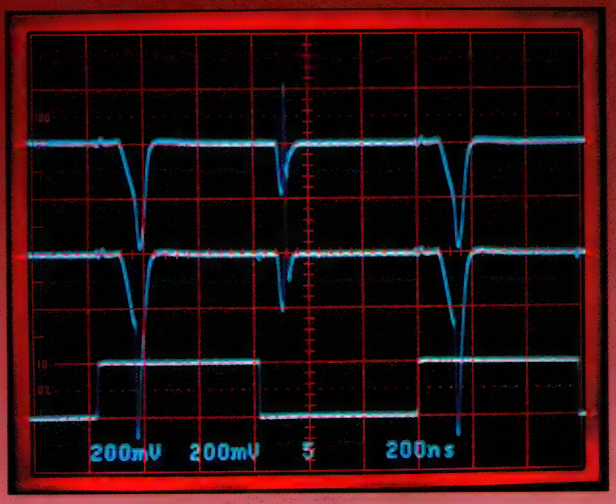


LT1203

Output

Input

Logic



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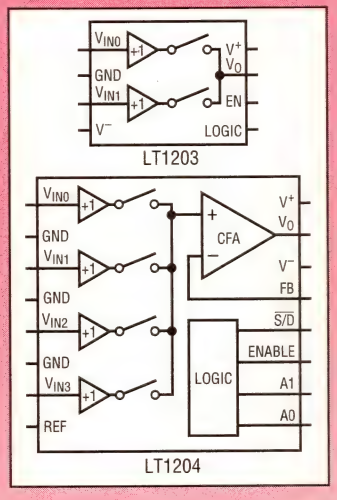

The LT1203/1205 are ideally suited for high speed graphics, multimedia, video routers or crosspoint applications delivering 150MHz bandwidth, 0.1dB gain flatness to 30MHz and Differential Gain/Phase of 0.02%/0.02° for true color fidelity.

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CIRCLE NO. 65

Pseudonoise generator doubles its speed

R N MUTAGI, SPACE APPLICATIONS CENTRE, AHMEDABAD, INDIA

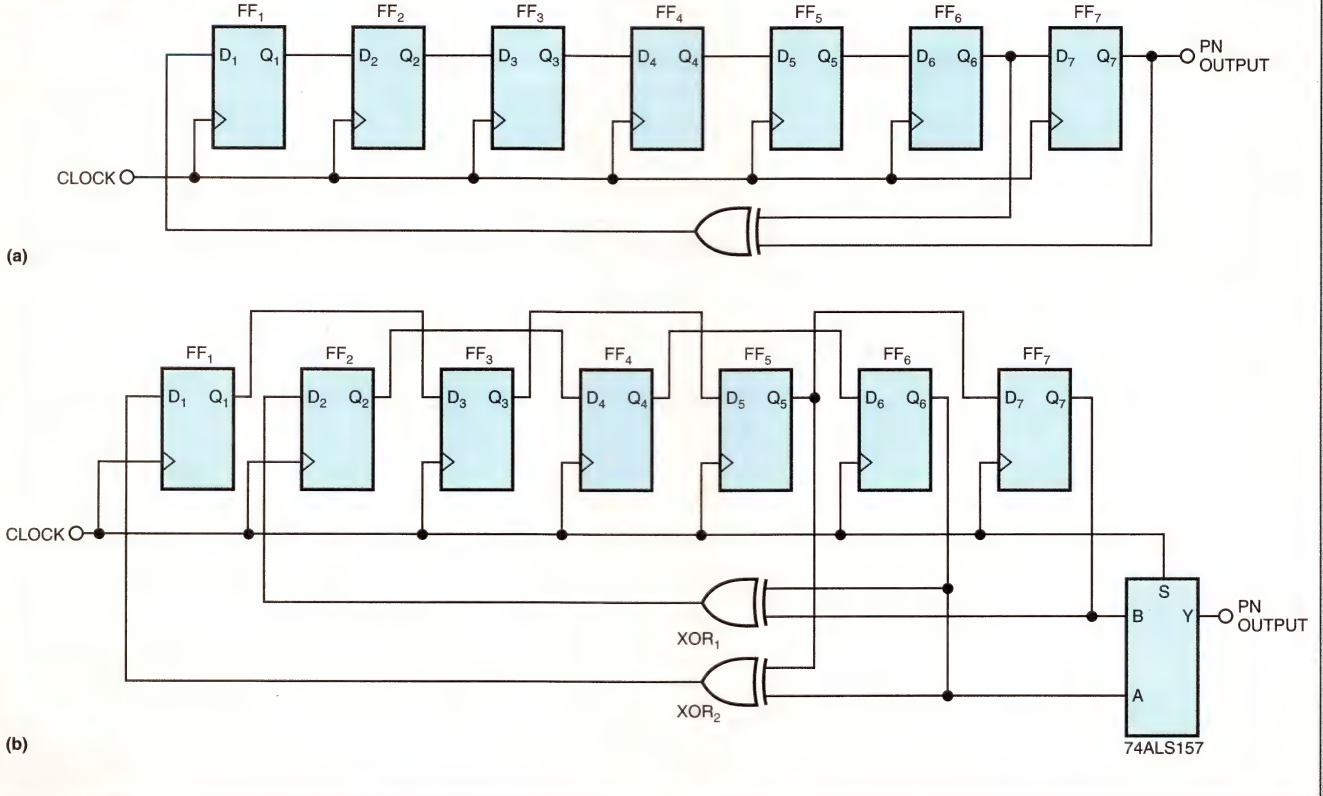
You can double the speed of a standard pseudonoise (PN) generator by using additional exclusive-OR gates and a fast 2:1 multiplexer. A PN generator built with an n-stage feedback shift register gives a maximal-length sequence of 2^N–1 bits. The upper limit of the PN-generator clock depends on the device logic family. For example, a PN generator built with 74LS74 flip-flops and a 74LS86 exclusive-OR gate has a top speed of 16 to 18 MHz. **Fig 1**'s circuit doubles this speed by implementing a phase difference of half the sequence length. The multiplexer then combines and outputs this phase difference at double the rate of the original circuit.

Fig 1a shows a seven-stage PN generator built with flip-flops and one exclusive-OR gate. The outputs of FF_6 and FF_7 are modulo-2. The exclusive-OR gate adds and feeds back the outputs to FF_1 to obtain a maximal-length sequence. **Fig 1b** shows the reconfigured generator that produces two sequences at the outputs of FF_6 and FF_7 with a 64-bit difference between them. The multiplexer can combine these sequences to produce a 32-MHz output because the sequences can be as fast as 16 MHz. The general procedure for the connection, for any register length N with taps specified by its characteristic equation, is as follows:

1. Cascade odd and even flip-flops separately. This circuit cascades FF_1, FF_3, FF_5, and FF_7 and FF_2, FF_4, and FF_6 separately.
2. Apply the exclusive-OR sum of the original taps to D_2 instead of D_1. In **Fig 1b**, XOR_1 adds Q_6 and Q_7 and applies the result to D_2.
3. Use a second exclusive-OR gate to add the taps from one stage ahead of the original circuit. XOR_2 adds Q_5 and Q_6 and applies the result to D_1.
4. Multiplex outputs Q_N and Q_{N-1}, which are Q_6 and Q_7 in this example. (DI #1640) EDN

To Vote For This Design, Circle No. 410

FIGURE 1



A standard seven-stage feedback shift register produces a PN sequence of 2^7–1 (a). Reconfiguring the register with an extra exclusive-OR gate and a 2:1 multiplexer (b) doubles the generator's speed.

Look-ahead approach tames large FPGA counters

JAY LEGENHAUSEN, CYPRESS SEMICONDUCTOR, SAN JOSE, CA

The T flip-flops and look-ahead technique in **Fig 1** allow you to program large, fast counters in FPGAs (field-programmable gate arrays). The look-ahead technique detects when the least-significant 4-bit block (Q_3 through Q_0) has the value 1110. The technique registers this event in a D flip-flop to create the look-ahead signal (LA_0 through LA_4). The look-ahead bit indicates that the most-significant counter bit should toggle at the next clock edge. Note: The look-ahead circuitry detects 1110_2 and not 1111_2 because the D flip-flop introduces one cycle of latency.

T flip-flops obviate the *n*-bit-wide OR gate that an *n*-bit counter would need if you used a conventional sum-of-products architecture. Otherwise, you need to use slower, multiple levels of logic to realize wide logic states in FPGAs.

Similarly, the look-ahead technique avoids the *n*–1-bit-wide AND gate that an *n*-bit counter based on T flip-flops requires. Such a wide AND gate would impose an excessive fan-out burden on some of the T flip-flops (**Fig 2**). For example, in the 24-bit counter in **Fig 1**, the most highly loaded D flip-flop has a fan-out of 4 instead of 23. (DI #1633)

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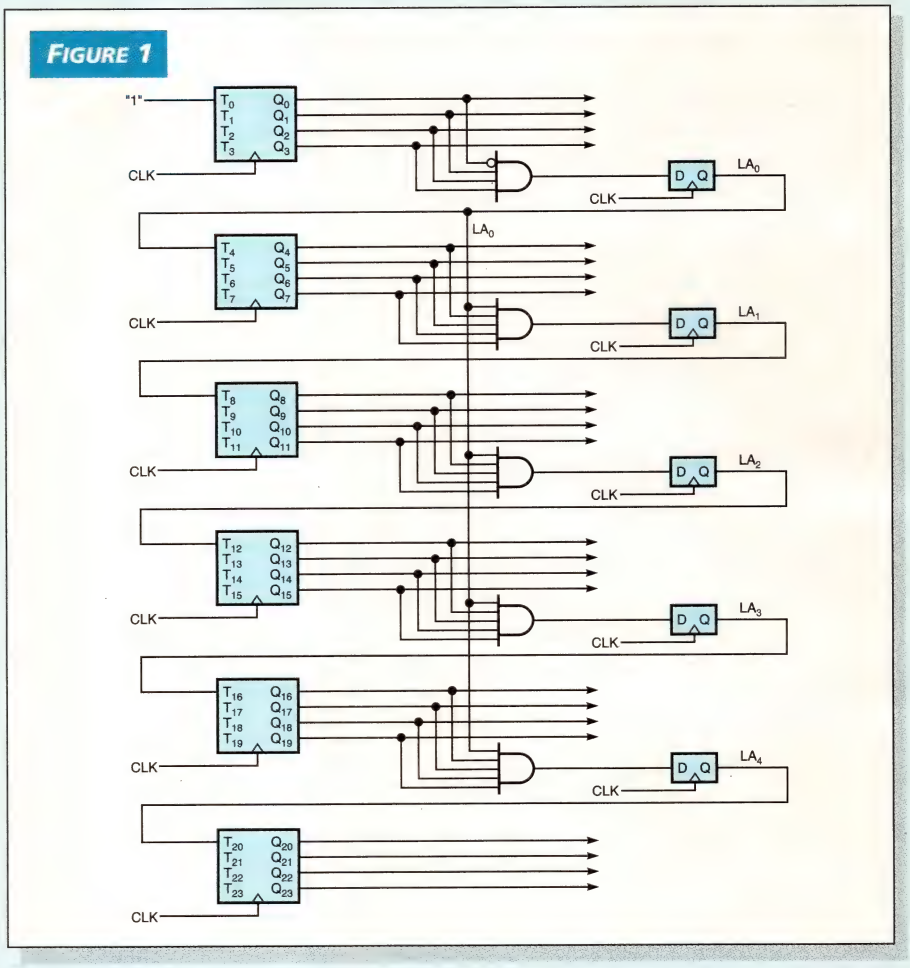
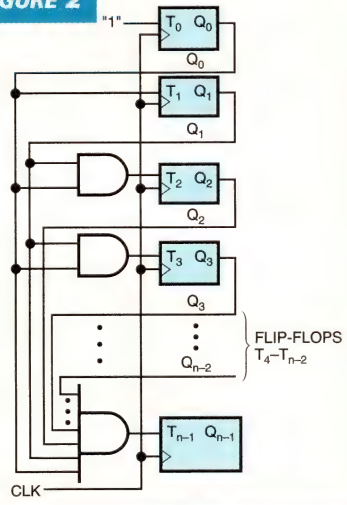
FIGURE 1



You can program large, fast counters in FPGAs using T flip-flops and the look-ahead technique.

FIGURE 2



The look-ahead technique avoids wide AND gates and excessive fan-out burdens.

Data									
D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	CLKOUT	Feedback
1	0	1	0	1	0	1	0	CLK/2	QH
1	1	0	0	1	1	0	0	CLK/4	QH
1	1	1	1	0	0	0	0	CLK/8	QH
1	1	1	1	1	1	1	1	CLK/16	QH

Data										
D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	CLKOUT	Feedback	Duty Cycle
1	0	0	0	1	0	0	0	CLK/4	QH	25%
1	1	0	0	1	1	0	0	CLK/4	QH	50%
1	1	1	0	1	1	1	0	CLK/4	QH	75%
1	1	0	0	0	0	0	0	CLK/8	QH	25%
1	1	1	1	0	0	0	0	CLK/8	QH	50%
1	1	1	1	1	1	0	0	CLK/8	QH	75%

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MSWA-2-20 (Absorptive)	DC-2.0	1.3	+27	40	3.45
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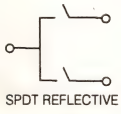
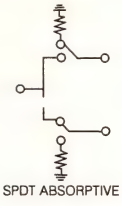
① Midband, 500-1000MHz ② Transmit ③ Receive

All Units: SOIC 8pin Package

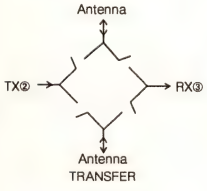
Actual Size



SPDT REFLECTIVE



SPDT ABSORPTIVE



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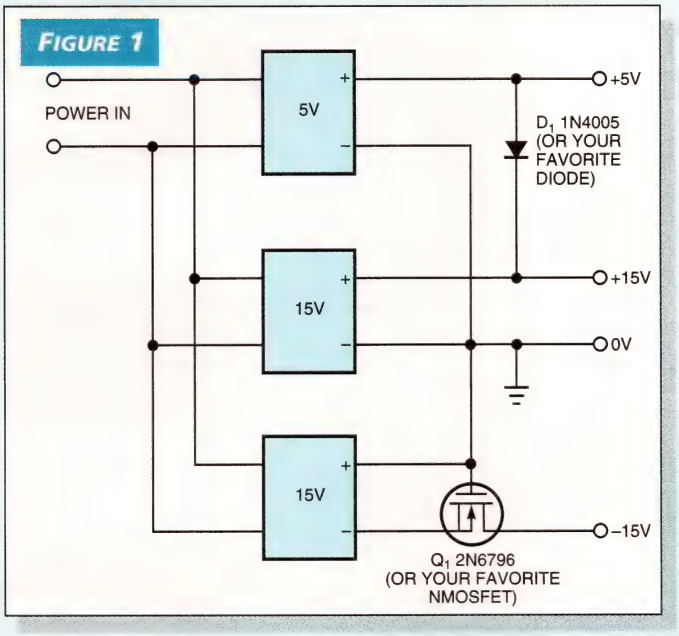
CIRCLE NO. 75

MOSFET beats Murphy's Law

PHIL HARVEY, TECHNOLOGY INTEGRATION INC, BEDFORD, MA

Consider it Murphy's Law: You buy two 15V supplies or one ±15V dual supply to power some op amps. Then, when the last QA inspector or first customer flips the switch, the power supply hangs up. This hang-up occurs because the positive supply yanks its output to positive. The negative supply reads this output as a reverse polarity before it has a chance to start up. So, the supply's negative regulator gives up. The output sits there just above 0V, draining positive current into its output clamp diode, and you have no negative supply diode. Some supplies have this problem, and some don't.



A simple n-channel MOSFET helps you break Murphy's law by ensuring startup of the negative power supply.

Let's assume that you've connected a start-up diode from the 5V power bus to the positive supply, which causes the positive supply to start up. **Fig 1** presents a simple solution using an enhancement-mode n-channel MOSFET to ensure that the negative supply also starts up. In this circuit, the 5V supply through diode D_1 forces the positive supply to start as before. However, if the –15V supply is a little slow starting up, Q_1 stays off, thereby decoupling the load until the supply's output voltage is sufficient to turn it on. At this point, the supply can't hang up because its output voltage is in the operating range and the supply has started.

Q_1 soon turns on and behaves like a short circuit (as long as you've picked a MOSFET with low enough on-resistance at 15V). Most NMOS types are quite happy with 15V on the gate and 30V on the drain. During start-up, Q_1 may have to handle full power, but only for an instant. For the rest of the time, the MOSFET is either all the way off (no current) or on (no voltage) and dissipates negligible power. A small-footprint NMOS device with no heat sink can handle the power dissipation. Naturally, if you decide to handle output short circuits, you have to plan for more power in Q_1. If there's no 5V supply to make life easy, another NMOS in the negative leg (or PMOS in the positive leg) does the same job for the positive power supply. (DI #1639) EDN

To Vote For This Design, Circle No. 412

Design approach simplifies signal conditioning

ROBERT S VILLANUCCI, WENTWORTH INSTITUTE OF TECHNOLOGY, BOSTON, MA

The low cost and wide availability of 8-bit microcontrollers, such as Motorola's MC68HC11, allow you to easily incorporate intelligence in pressure-measurement systems. Your main challenge is to signal-condition the sensor's small, differential bridge signal into a single-ended output voltage that the µC's A/D converter, running off 5V, can accept. You can easily identify circuit functions and design hardware by graphing the required system response and using basic math. You can apply this general design technique to all linear sensors.

Consider a design that must convert pressure ranging from 0 to 5 psi to a 0.5 to 4.5V signal. **Fig 1a** illustrates the design requirements of the signal-conditioning circuit. The equation for the analog interface of this linear system design is

$$V_{ADC} = (800\ mV/psi)P_{IN} + 0.5V. \quad (1)$$

In **Eq 2**, the sensitivity of the pressure sensor equals 5 mV/psi when you drive the sensor from a 5V reference

$$V_1 - V_2 = (5\ mV/psi)P_{IN}. \quad (2)$$

The signal-conditioning circuit's design equation describes the electronics needed to interface the sensor to the µC. You can write this equation by solving **Eq 2** for P_{IN} and substituting

$$V_{ADC} = 160\ (V_1 - V_2) + 0.5V. \quad (3)$$

The design should amplify the pressure sensor's differential output signal, V_1–V_2, by a gain of 160. You must convert the result to a single-ended voltage, V_{ADC}, and offset this voltage by 0.5V. The gain requirements are moderately high. Conse-

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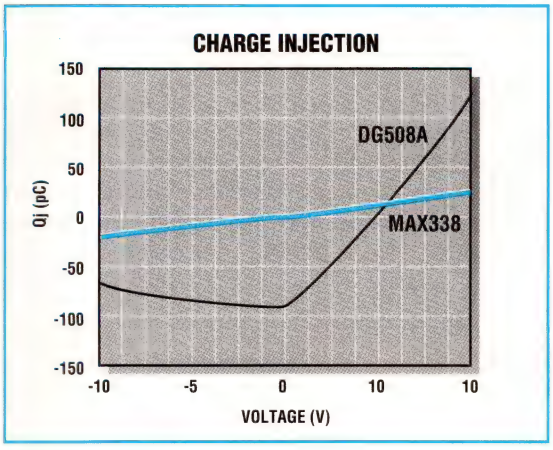

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quently, you should amplify the signal in two stages: an instrumentation amplifier with a gain of 10 followed by a gain/offset stage. **Eq 4** characterizes the instrumentation amplifier voltage (V_{IA})

$$V_{IA} = 10\,(V_1 - V_2). \qquad \textbf{(4)}$$

You must solve **Eq 4** for V_1–V_2 and substitute the resulting expression into **Eq 3** to complete the interface design. The result of this equation yields **Eq 5**, which describes the final gain/offset stage:

$$V_{ADC} = 16\,(V_{IA}) + 0.5V. \qquad \textbf{(5)}$$

Fig 1b shows the implementation of this design. The SCX15DNC sensor measures pressure and outputs a differential signal (see **Eq 2**). The differential signal drives the single-supply instrumentation amplifier, IC_1. The circuit wires IC_1 for a gain of 10. IC_2's noninverting amplifier and the passive adder, comprising R_1, R_2, and R_3, complete the design by satisfying **Eq 5**. A passive adder can only attenuate signals. Therefore, you must first divide **Eq 5** by 20—or any gain greater than 16—to yield a linear equation of the form Y=mX+b as follows:

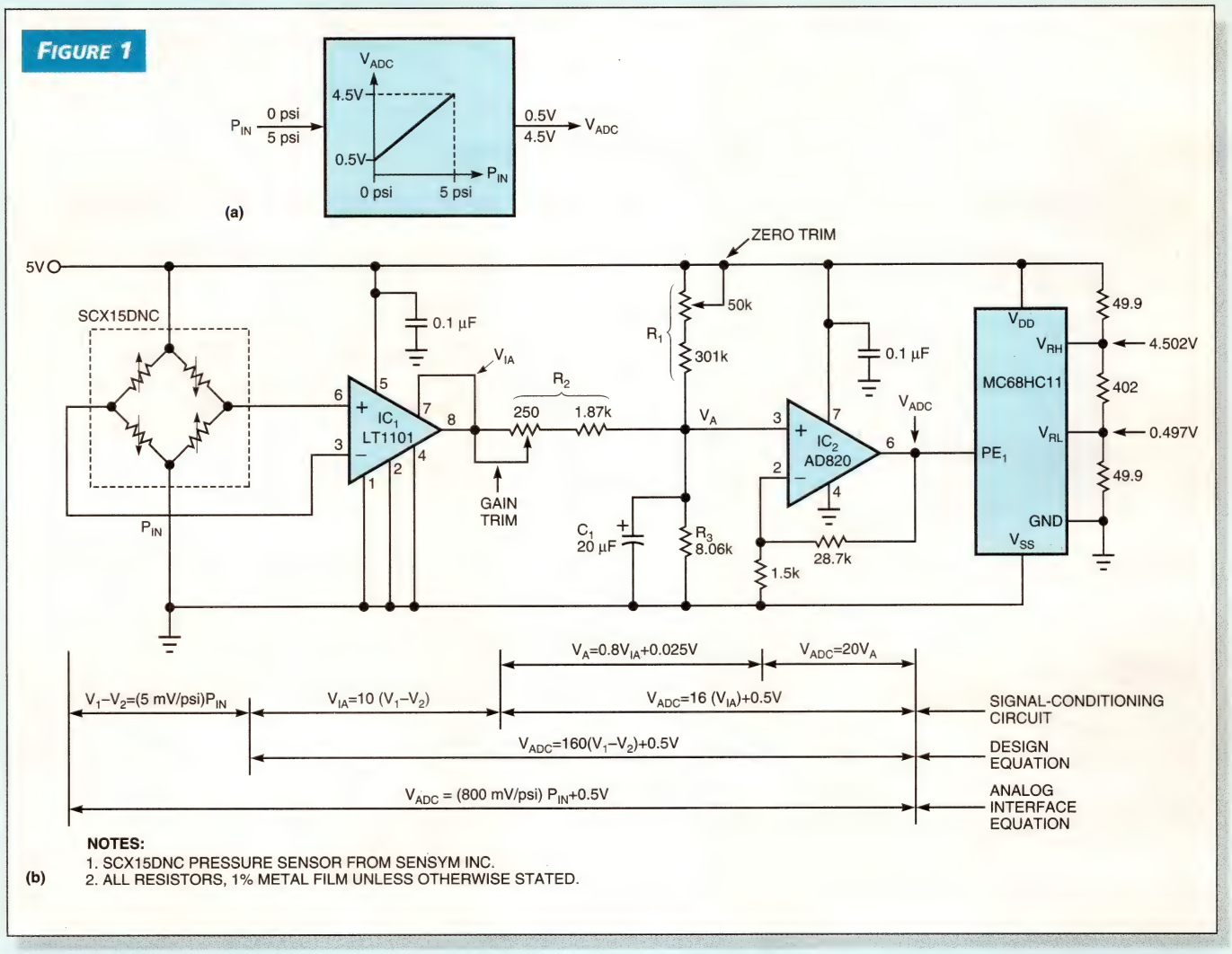
$$V_A = 0.8\,(V_{IA}) + 0.025V. \qquad \textbf{(6)}$$

The passive adder combines the m and b terms. IC_2's gain-of-20, rail-to-rail op amp reestablishes system gain requirements.

Apply 0 psi and adjust the zero-trim potentiometer until V_{ADC} equals 0V to calibrate the circuit. Next, apply 5 psi and adjust the gain-trim potentiometer for a 4.5V output. The zero and gain trims interact. Therefore, you should repeat these adjustments until both points stay fixed. Finally, adding C_1 to the passive adder before the final gain stage creates a lowpass filter with a pole at approximately 5 Hz. This filter prevents power-frequency noise from corrupting the sensor's output. (DI #1643) EDN

To Vote For This Design, Circle No. 413

FIGURE 1



Breaking down design requirements graphically (a) and writing a series of basic equations help you in the design of this sensor signal-conditioning circuit (b).

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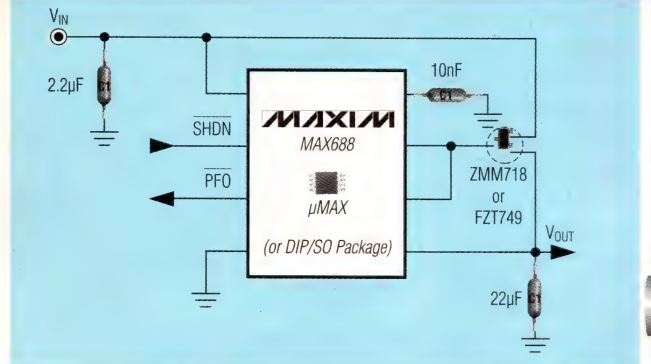

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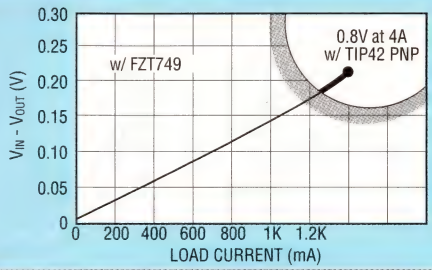
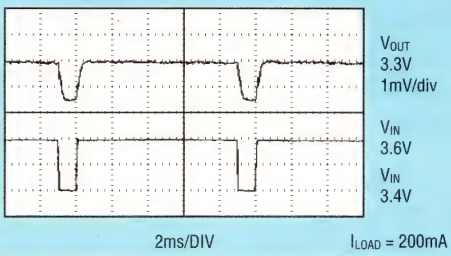
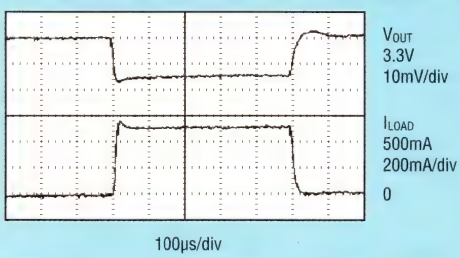


BEST LINE TRANSIENT RESPONSE



BEST LOAD TRANSIENT RESPONSE



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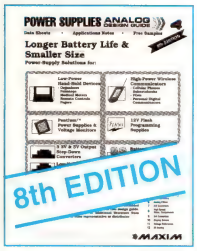

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CIRCLE NO. 84

Fast rectifier circumvents input-level effects

MICHAEL STEFFES AND JIM RIPHAHN, COMLINEAR CORP, FT COLLINS, CO

All diode-based rectifier circuits suffer from a signal-level-dependent frequency response. This response occurs because the dynamic impedance of the diodes varies as the signal level changes. The result is a slower frequency response and distorted rectified outputs at low signal levels compared with high levels.

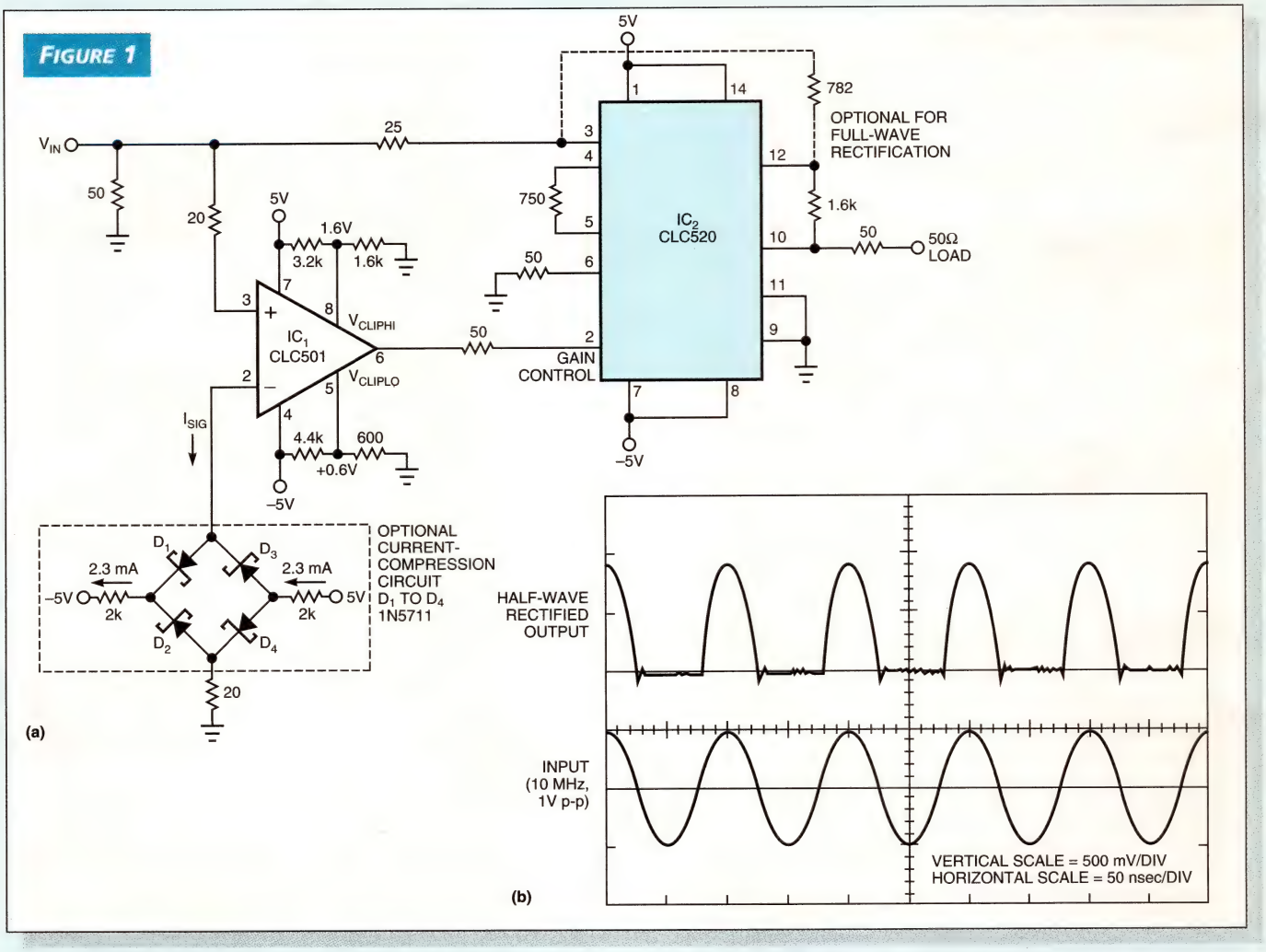
An alternative approach to a half-wave rectifier is to use the input-signal polarity to control the signal channel gain. The input signal shuts down the gain for one polarity and passes the signal on for the other.

You need a high-speed comparator to detect zero crossings and an adjustable gain stage with broadband signal and gain-control channels to implement this approach (**Fig 1a**). A wideband, current-feedback amplifier with an output-clipping feature acts as the comparator to control a high-speed AGC amplifier's gain. The polarity of I_{SIG} controls the comparator operation. IC_1 connects the comparator operation and a flexible output voltage that matches the gain control range of IC_2. You can extend the comparator's dynamic range by connecting the optional compression network to the inverting node of IC_1. IC_2 is an AGC amplifier with a channel bandwidth greater than 200 MHz and can switch from full on to off in less than 2 nsec.

Fig 1b shows test results with a 10-MHz, 1V p-p input. If you carefully match the delays for the signal and gain-control channels, you can achieve higher speeds. You can produce a full-wave rectifier by summing the original input into the AGC's output with the correct gain. The circuit passes negative half-cycles around the gain-control path directly to the output. This path and the gain-controlled path act on positive half cycles. (DI #1645) EDN

To Vote For This Design, Circle No. 414

FIGURE 1



The input signal polarity of this rectifier (a) controls the gain of the negative and positive half cycles using a high-speed comparator and AGC amplifier. Waveforms (b) are the test results with a 10-MHz input signal.

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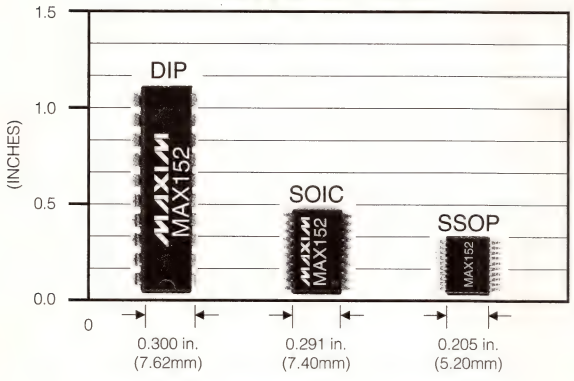

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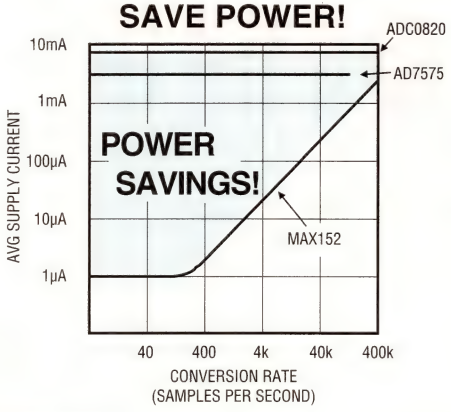

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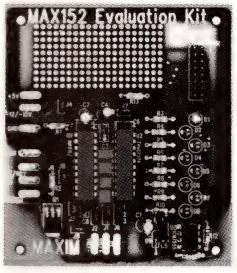

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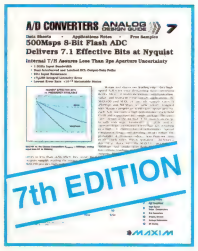

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CIRCLE NO. 83

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The winning Design Idea for the August 4, 1994, issue is entitled "RC network eliminates precision reference," submitted by Christophe Basso of European Synchrotron Radiation Facility (Grenoble, France).

LINEAR TECHNOLOGY

DESIGN NOTES

PCMCIA Socket Voltage Switching – Design Note 93

Why Your Portable System Needs SafeSlot™ Protection

Doug La Porte

Introduction

Most portable systems have built-in PCMCIA sockets as the sole means of expansion. The requirements of the PCMCIA specification have led to some confusion among system designers. This Design Note will attempt to lessen the confusion and highlight other practical system issues.

Host power delivery to the PC card socket flows through two paths: the main V_{CC} supply pins and the VPP programming pins. Both supplies are switchable to different voltages to accommodate a wide range of card types. The V_{CC} main card supply must be capable of delivering up to 1A at either 3.3V or 5V. The 1A rating is an absolute maximum derived from the contact rating of 500mA per pin for both V_{CC} pins and assumes that both pins are in good condition and current is shared equally. One of the most stringent actual current requirements is during hard drive spin-up. Present hard drives require 5V at 600mA to 800mA for a short duration during spin-up. Current draw drops to 300mA to 420mA during read and write operations. A low switch resistance on the 3.3V switch is critical to assure that the specified 3.0V minimum is maintained. The VPP supply must source 12V at up to 120mA and 3.3V or 5V at lesser currents. The VPP supply is intended solely for flash memory programming. The 120mA current requirement allows writing to flash devices and simultaneously erasing two other parts as required by many flash drives.

The host PCMCIA socket designer also has several other practical aspects of the design to consider. The exposed socket pins are vulnerable to being shorted by foreign objects such as paper clips. In addition the users will attempt to install damaged cards. In short, once in the hands of the consumer, the designer and manufacturer have little control over use and abuse. To ensure a robust system and a satisfied customer, switch protection features such as current limiting and thermal shutdown are a necessity. The nature of the PC cards and portable systems requires the card being powered on and off as needed to conserve power. Many PC cards have large input capaci-

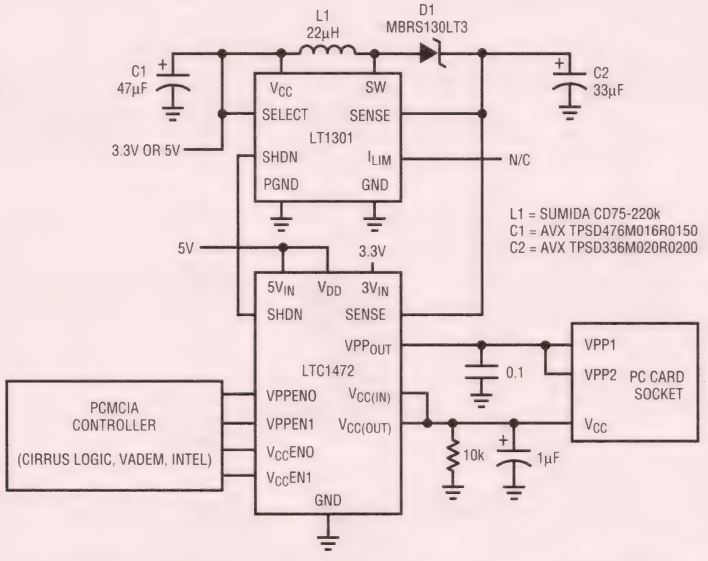

Figure 1. Typical LTC1472 Application with the LT1301 3.3V Boost Regulator

tance and draw over 2W. The power up/down sequencing can put demanding transient requirements on your system power supply. To make the transient response of the system supply manageable, the PCMCIA switch should have break-before-make switching, controlled rise and fall times and current limiting. The slowed rise time coupled with current limiting are critical in controlling the immense in-rush current difficulties seen when charging the large input capacitance of many cards

LTC®1472: Complete V_{CC} and VPP PCMCIA Switch Matrix with SafeSlot Protection

The LTC1472 is a complete, fully integrated V_{CC} and VPP switch matrix that addresses all of the PCMCIA socket switching needs. Figure 1 shows a typical LTC1472 application used in conjunction with the LT®1301 to supply 12V for flash memory programming. The LTC1472's logic inputs allow direct interfacing with both logic high and logic low industry standard controllers without any external glue logic. The LTC1472 is available in the space saving narrow 16-pin SOIC package. The V_{CC} switch's $R_{DS(ON)}$ is 0.14Ω to support the 1A current requirement. The V_{CC} output is switched between 3.3V, 5V and high impedance. The VPP output pin is switched between 0V, V_{CC}, 12V and high impedance. Table 1 shows the V_{CC} and VPP truth tables.

Table 1. LTC1472 Truth Table

V_{CC} Switch

V_{CC}EN0	V_{CC}EN1	$V_{CC(OUT)}$
0	0	off
1	0	5V
0	1	3.3V
0	1	off

VPP Switch

VPPEN0	VPPEN1	VPP_{OUT}
0	0	0V
0	1	$V_{CC(IN)}$
1	0	VPP_{IN}
1	1	Hi-Z

The LTC1472 features SafeSlot protection. The built-in SafeSlot current limiting and thermal shutdown features are vital to ensuring a robust and reliable system. The V_{CC} current limit is above 1A to maintain compatibility with all existing cards yet provide protection. The VPP current limit is above 120mA to also maintain compatibility. All switches are break-before-make type with controlled, slowed rise and fall times for minimal system supply impact. In-rush current, from even the largest card input capacitance, is kept under control by the LTC1472's slowed rise-time switching and current limiting.

The LTC1472 has on-chip charge pumps for switch driving. For this reason, the device does not require a continuous 12V source. Most of the time the LT1301 is in shutdown mode, consuming only 10μA. The LT1301 becomes operational only during flash memory programming. The LTC1472 itself conserves power by going to a low 1μA standby mode when V_{CC} and VPP outputs are switched off. The use of the LT1301 is optional. Any suitable 12V supply can be directly connected to the VPP_{IN} pin. Caution should be exercised when using a general purpose 12V supply; make certain that it does not have spikes or transients exceeding the flash memory 14V maximum voltage rating and that the regulation is within the 5% flash memory tolerance.

Conclusion

PCMCIA sockets are the preferred method of expansion in portable systems. As these devices proliferate to less sophisticated users, there will be greater opportunity for abuse. To counter this trend the portable system design must take safeguards to protect the system. The high level of integration, SafeSlot protection features and controlled rise and fall switching make the LTC1472 the ideal solution for portable systems.

Linear Technology has a family of PCMCIA socket voltage control products to suit a broad range of customer's needs. Table 2 lists the present part offerings. For assistance on your specific design needs, call Linear Technology.

Table 2. Linear Technology's PCMCIA Host Socket Voltage Control Products

Part Number	Remarks
LT1312	VPP Linear Regulator
LT1313	Dual Slot VPP Linear Regulator
LT1314	Low Cost V_{CC} and VPP Switch Matrix
LT1315	Dual Low Cost V_{CC} and VPP Switch Matrix
LTC1470	Complete SafeSlot Protected V_{CC} Switch Matrix
LTC1471	Dual Complete SafeSlot Protected V_{CC} Switch Matrix
LTC1472	Complete SafeSlot Protected V_{CC} and Switch Matrix

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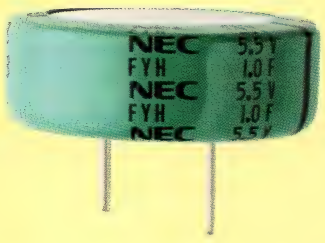
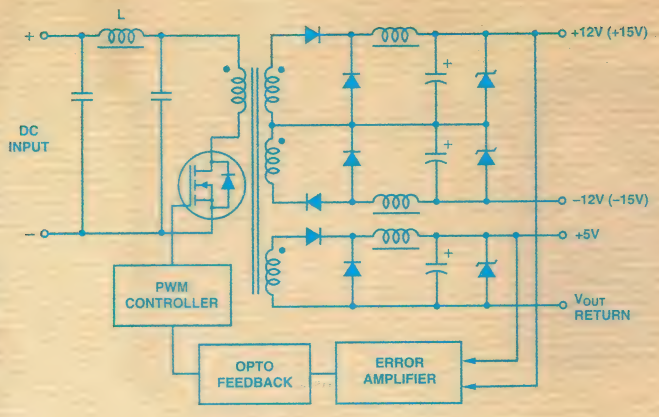


We're not exactly sure how many engineers it takes to change a battery, but we seem to remember that it's a lot. And anyway, it's more than it takes to change a supercapacitor. **Because supercapacitors don't really need to be changed.** So they're a lot better for back up power than batteries. Especially if you're designing with microcontrollers, or microprocessors and SRAMs. They're also better for applications like security systems and medical equipment and industrial controls. (Or whenever it's really inconvenient or difficult to replace a battery.) And they're available in capacitances from .01 Farad to 2.2 Farads and 3.5 volts to 11 volts. So you can get up to 30 days of back-up power. In other words—you and your customers will have one less thing to worry about. Of course, you can also use them as an adjunct to your batteries. But in a lot of situations, you can just substitute a supercapacitor for a lithium or nicad battery. So you won't need a battery holder. And that way, you'll have a little more space to work with. (They're also safer, and better for the environment.) So if you can think of some things you'd rather not change, call **NEC Electronics Inc.** at **1-800-366-9782** and ask for info pack #904.

NEC

XWR Series



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TWR-5/3000-12/500-D12	+5 ±12	3000 ±500	85 125	±1.0% ±1.0%	±2.0% ±5.0%	24	9-36	25/1020	80%	$76
TWR-5/3000-12/500-D48 ③	+5 ±12	3000 ±500	85 120	±1.0% ±1.0%	±2.0% ±5.0%	48	18-72	15/510	80%	$76
TWR-5/3000-15/500-D12	+5 ±15	3000 ±500	85 150	±1.0% ±1.0%	±2.0% ±5.0%	24	9-36	25/1020	80%	$76
TWR-5/3000-15/500-D48 ③	+5 ±15	3000 ±500	85 175	±1.0% ±1.0%	±2.0% ±5.0%	48	18-72	15/510	80%	$76

① 5V output, 10-100% load. ±12V or ±15V outputs, balanced loads, 20-100% load. ② Nominal line voltage, no load/full load conditions. ③ Available 12/94.

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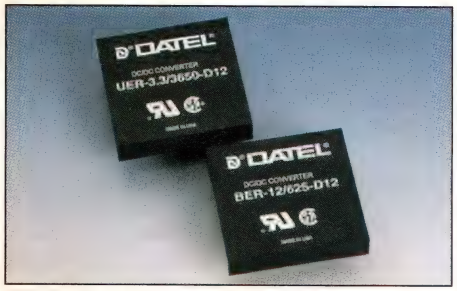

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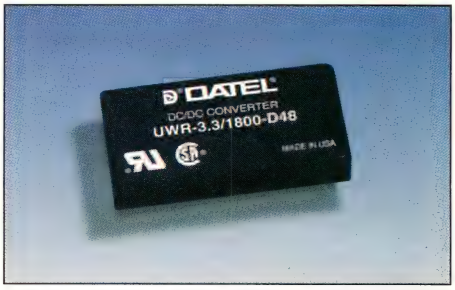

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128-macrocell complex PLD implements counters at up to 100 MHz. The CY7C342B has 12-nsec propagation delays on some paths. According to the company, the device offers 2500 equivalent usable gates. The device is organized as eight logic-array blocks (LABs) with 16 macrocells in each LAB. The devices come in 68-pin HLCC, PLCC, PGA, and flatpack packages; the 12-nsec version in a PLCC package is $36.30 (10,000). **Cypress Semiconductor**, San Jose, CA. (408) 943-2600. **Circle No. 352**

12V servo/motor speed-control IC eliminates torque ripple. The 32H-6826 speed-control IC uses the company's SilentSpin commutation technique to eliminate torque ripple, resulting in reduced acoustic noise, which, in turn, allows higher bit densities on hard-disk drives. The IC comes in a 64-lead TQFP and costs $8 (10,000). **Silicon Systems**, Tustin, CA. (714) 573-6200. **Circle No. 353**

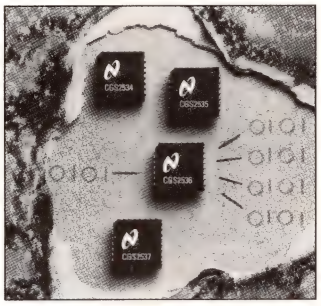
Solder-bumped Flip Chip array packaging for semicustom analog bipolar chips. The Genesis 3400 Flip Chip has 18 I/O tin-lead solder bumps; two predesigned functional blocks (a shunt regulator and trimmable 3% voltage reference); integral 2000V ESD-protection structures; and an uncommitted array of 118 transistors, 400 resistors, and two capacitors. Maximum rated power-supply voltage is 20V. The reflow-mounted Flip Chip requires less substrate area; it has lower finished assembly than wire-bonded bare die (or any surface-mount package). NRE costs for layout and integration are typically $5000 to $10,000. Typical production cost, $1.60 (50,000 units/year). **Cherry Semiconductor Corp**, East Greenwich, RI. (401) 885-3600. **Circle No. 354**

2A dc/dc step-down controllers use only 100-mA quiescent supply current. The 5V output MAX1649 and 3.3V output MAX1651 step-down controllers have >90% efficiency for 10-mA to 1.5A loads. A 5-μA current in shutdown mode further helps extend battery life. The controllers work with external P-channel MOSFETs, resulting in a 300-mV dropout with 400-mA loads. The controllers operate at up to 300 kHz, allowing the use of 22-μH inductors and small capacitors. You can also adjust the output voltage using external resistors. From $1.60 (1000). **Maxim Integrated Products**, Sunnyvale, CA. (408) 737-7600, ext 6087. **Circle No. 355**

Low-cost fader IC blends multiple inputs for special video effects. The EL4453C fader subsystem includes a pair of two-quadrant multiplier/gain controls. The four sets of inputs include two differential signal inputs, a differential fade-controlling input, and a fourth differential input to complete a feedback loop with the output or to sum a third input. No additional components are needed to generate picture-in-picture special effects. $3.95 (1000). **Elantec Inc**, Milpitas, CA. (408) 945-1323. **Circle No. 356**

3V LCD controller/driver has built-in serial-data interface. The HD66712 has a built-in serial-data interface that provides a one-third reduction in the number of signal lines needed to control a four-line×12-character, 5×8-dot-matrix display. The device also includes an LDC drive-generation circuit that multiplies drive voltage by up to a factor of three, allowing system operation from a 3V supply. The chip can also drive two-line, 24-character displays. Available in a 128-pin QFP or a TAB package from $8.50 (100). **Hitachi America Ltd, Semiconductor and IC Division**, Brisbane, CA. (800) 285-1601, ext 24. **Circle No. 357**

Video processor for multimedia applications. The PC View+ video processor provides Moving Picture Experts Group (MPEG) CD-ROM playback acceleration, TV in a PC, and live-video capture and playback. The video processor interfaces directly to a VESA Advanced Feature Connector (VAFC), which enables the transfer of data to any graphics board supporting this interface. $20 (10,000). **Trident Microsystems Inc**, Mountain View, CA. (415) 691-9211. **Circle No. 358**



125-MHz clock-generation chips deliver up to 16 low-skew outputs. The CGS253x family of clock-generation chips provides a maximum pin-to-pin skew of 350 psec, a maximum part-to-part skew of 650 psec, and a maximum propagation delay of 3.5 to 4.5 nsec. The family operates with mixed 3.3 and 5V IC configurations. The CGS2534V drives four to 16 clocks with inverted outputs that are useful for selecting addresses of DRAMs. The CGS2537 adds an on-chip 8Ω resistor to the outputs to aid in line termination and to reduce undershoot. The CGS2535V and CGS2536V are for 3.3 and 5V operation. The 2535 offers four to 16 clock drivers with noninverting outputs. The 2536 provides noninverting and inverting 1 and 0.5× outputs. $6.90 (1000). **National Semiconductor Corp**, Santa Clara, CA. (800) 272-9959. **Circle No. 359**

ATM physical-media-interface transceiver chip set uses Ethernet wiring. The IDT77103/IDT77104 transceiver chip set provides the physical-media interface for low-cost 25-Mbps asynchronous-transfer-mode (ATM) networks. ATM at this speed can operate over voice-grade wiring normally used by Ethernet but is up to five times faster than Ethernet or Token Ring networks. The IDT77103 transmission-convergence chip provides the necessary scrambling/descrambling functions, encoding, and NRZI conversion. The IDT77104 physical-media-dependent chip performs transmit and receive functions, such as line equalization and PLL clock and data recovery. $35 (10,000). **Integrated Device Technology Inc**, Santa Clara, CA. (800) 345-7015. **Circle No. 360**

DRAM controller has 80-MHz PLD sequencer. The BiCMOS 74ABT4764 DRAM controller features an 80-MHz PLD sequencer to suit dual-port or burst-memory systems. The controller interfaces directly to CISC or RISC processors or DMA channels and arbitrates between memory requests from any two of these devices and refresh logic. The controller has 16-column address-strobe outputs, four-row address-strobe outputs, and the ability to directly address up to 4 Mbytes of memory. For burst-mode transfers, the IC includes 11-bit column- and row-address counters and an

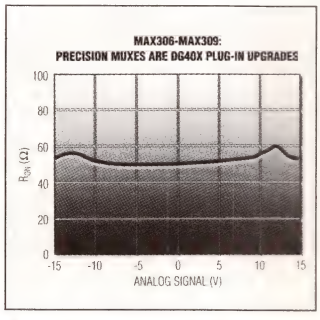
11-bit loop counter. Using a 64-bit data path, the IC makes DMA transfers at up to 640 Mbytes/sec. Price is $30 (1000). **Philips Semiconductors**, Eindhoven, The Netherlands. (31) 40 722091. **Circle No. 361**

Programmable divider suits fractional-N PLL systems. The 1.1-GHz SP8713 has division ratios of 64, 65, or 72 and targets fractional-N systems for PLLs in telephone or radio products. RF inputs are internally biased to allow capacitive coupling, and outputs interface directly to CMOS devices. The bipolar IC operates on 2.7 to 5.5V and consumes 4.7 mA in normal mode and 20 μA in economy mode. Price is $3. (1000). **GEC Plessey Semiconductors**, Swindon, UK. (44) 793 518481. **Circle No. 362**

1-Mbit flash memory has 10×14-mm TSOP package. The M28F102 100-nsec flash memory has 64k×16-bit organization and a 100-μA max standby current. The 5/12V device provides 10-μsec typ byte programming and 1-sec chip-erase. The 16-bit word and 10×14-mm, 40-pin TSOP outline suit hard-disk-drive applications. **SGS-Thomson**, Agrate, Italy. (39) 39 603 5901. **Circle No. 363**

LAN-specific embedded controllers support Ethernet and Token Ring LANs. The AXT6100 is a single-chip, 32-bit embedded controller with an Ethernet network controller. It costs $57.50 (1000). The AXT6200 contains both Ethernet and Token Ring network controllers in a single embedded controller for LAN products that use either protocol. It costs $75 (1000). These embedded controllers are designed for intelligent stand-alone LAN products, including router, intelligent hubs/concentrators, bridges, communications/fax servers, remote-LAN-access products, Simple Network Management Protocol (SNMP)-managed UPSs, and wireless LANs. **Axis Technologies**, Danvers, MA. (508) 777-7957. **Circle No. 364**

3.3V voltage regulators handle 7.5A. The EZ108x series of positive voltage regulators includes 1.5, 3, 5, and 7.5A versions. Output voltage is 3.3V or variable from 1.3 to 4V. Line and load regulation are 0.015 and 0.1%, respectively. The series is pin-compatible with Linear Technology's LT108x series and comes in TO-220, TO-247, TO-263, and TO-3 packages. Price of EZ1085CT (3A) is £1.13 (1000). **Semtech**, Glenrothes, UK. (44) 592 773520. **Circle No. 365**



Analog multiplexers offer low on-resistance. The MAX306, MAX307, MAX308, and MAX309 are plug-in replacements for the DG408, DG409, DG508A, and DG509A industry-standard analog multiplexers; these plug-ins offer improved characteristics. The devices have less than 100Ω on-resistance, which is matched within 5Ω between channels and remains flat over the specified analog signal range within 7Ω. The multiplexers have <10-pC charge injection and >2000V electrostatic protection. The 16-channel MAX306 and dual eight-channel MAX307 start at $3.87 (1000). The eight-channel MAX308 and dual four-channel MAX309 start at $2.50 (1000). **Maxim Integrated Products**, Sunnyvale, CA. (408) 737-7600, ext 6087. **Circle No. 366**

12-bit ADC consumes 1 mW at 3.3V. The 12-bit MB8810A ADC uses two modes of successive approximation and has a 16-μsec conversion time. The IC has a sample-and-hold facility, and the serial output suits direct interfacing to a microcontroller. Power consumption is 4 mW at 5V and 1 mW at 3.3V. Packaged in a 16-pin SSOP, the IC costs $2.36 (1000). **Fujitsu**, Maidenhead, UK. (44) 628 76100. **Circle No. 367**

Average-current-mode power-factor controller reduces power-line harmonic distortion. The TK83854 is a licensed second source for the Unitrode UC3854. The device may be used in power supplies to help satisfy the IEC-555 requirement for power-line harmonic distortion. In addition to reducing power-line harmonics, an average-current-mode power-factor controller used in off-line supplies may increase the maximum available output power from an ac wall outlet up to 50% without needing to upgrade the circuit breaker and wiring. $3 (1000). **Toko America Inc**, Mount Prospect, IL. (708) 297-0070. **Circle No. 368**

10-bit ADC runs at 50M samples/sec. Versions of the 10-bit TDA8760 ADC run at 20M, 40M, and 50M samples/sec and consume 850 mW at 5V. When sampling a 4.43-MHz full-scale input at 40M samples/sec, the ADC has an S/N ratio of >56 dB and a THD figure of –65 dB. External reference input allows you to set the input signal range up to 1.5V p-p. The ADC has three-state TTL outputs in binary or two's-complement code. In a 44-pin PLCC, a 40M-sample/sec version costs $25. **Philips Semiconductors**, Eindhoven, The Netherlands. (31) 40 722091. **Circle No. 369**

256-kbit to 4-Mbit E-PROMs in 60- and 70-nsec speed grades. By screening standard production for faster speeds, the company can produce 32k×8, 64k×16, 256k×8, and 512k×8 EPROMs with 70-nsec access times; 64k×8 and 128k×8 EPROMs are available with 60-nsec access times. From $3.70 (1000) for the 32k×8 M27C256B-70XF1 to $10.70 (1000) for the 512k×8 M27C4001-70XF1. **SGS-Thomson Microelectronics**, Lincoln, MA. (617) 259-0300. **Circle No. 370**

16-bit ADC converts 2M samples/sec. The ET1662 sampling ADC provides a spurious-free dynamic range of –100 dB and an S/N ratio of 82 dB. The device has an input bandwidth of 30 MHz for super Nyquist conversion applications. Differential nonlinearity is ±0.5 LSB. Commercial version, $895 (100); premium version, $995. **Edge Technology Inc**, Waltham, MA. (617) 899-7900. **Circle No. 371**

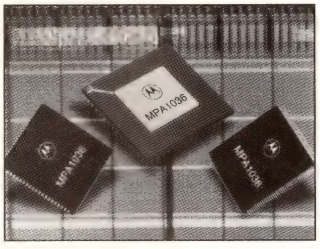
PCMCIA card-side I/O controller. The MSM60801 card-side PCMCIA controller adapts an I/O peripheral (such as a UART in a fax/modem application) to the PCMCIA interface in a PC. The I/O controller works with all Type II PCMCIA cards and can handle card-information structures, interrupt conflicts, and general handshaking between the card and host-side controller on the motherboard. Power consumption is <2 mW during power down and 20 mW during normal operation. The technology was licensed from Dr Neuhaus Engineering GmbH of Hamburg, Ger-

many. In a 100-pin TQFP, $5.75 (10,000). **Oki Semiconductor**, Sunnyvale, CA. (408) 720-1900.
Circle No. 372

8- and 16-Mbit EPROMs. The M27C801 UV EPROM is organized as a 1M×8-bit device and has access times of 120 nsec ($25 (1000)) or 100 nsec ($29 (1000)). The devices are housed in a CERDIP32 package or as a one-time-programmable device in a TSOP32 package. The 16-Mbit M27C160 is available in ×8 or ×16 organization and has access times of 150 nsec ($54 (1000)) or 200 nsec ($45 (1000)). The 16-Mbit devices have a CERDIP42 package. **SGS-Thomson Microelectronics**, Lincoln, MA. (617) 259-0300. **Circle No. 373**

V.34 complete modem chip set loaded with ITU-T V.34 code. The HSM-288LCF modem chip set meets the full 28.8-kbps standard. The chip set is a combination of hardware and software that supports data rates up to V.34 28,800-bps data, fax speeds up to V.17 14,400 bps, AT Command Set, V.42 and MNP4 error correction, V.42bis and MNP5 data compression, Class 1 send and receive fax, autosync, and flash download features. The chip set includes the DSP1633F integrated DSP and codec chip, the VALV33 digital-interface device, and the C882-29 29-MHz µC. Chip set, $79 (10,000); HSM288PCF PCMCIA chip set, $89 (10,000). **AT&T Microelectronics**, Allentown, PA. (800) 372-2447. **Circle No. 374**

FPGA offers 26,000 gates. The ATT2C26 is currently the largest available member of the company's ORCA FPGA family. Using a 0.5-µm three-layer metal process, the device has a 150-MHz clock rate. Pin-to-pin and clock-to-out delays are <11 nsec, which meets the PCI bus specification. The device has 384 user I/O pins, 36,864 bits of user RAM, and 2304 flip-flops in the core-logic cells. The FPGA now costs $720 (1000), but the company expects volume price to decrease to $395 by the middle of 1995. **AT&T Microelectronics**, Allentown, PA. (800) 372-2447. **Circle No. 375**



Fine-grained SRAM-based FPGA offers 3600 core-logic cells. The MPA1036 has 900 internal flip-flops, 240 I/O-cell flip-flops, and 120 I/O pins. The company rates the device at 8000 gates. $125 (100). **Motorola Semiconductor Products Sector**, Phoenix, AZ. (602) 655-2594.
Circle No. 376

2-Mbit synchronous self-timed SRAMs available in 11-, 12-, and 15-nsec speeds. The CXK779-20TM/YM is organized as a 256k-word×9-bit memory. According to the company, the devices provide fast data access in cache-memory applications for Pentium and RISC SPARC processors. Input registers, high-speed memory, and output registers are integrated into a single monolithic circuit, so all registers are triggered by an external clock. A complex off-chip write pulse is thus eliminated. The devices come in a 44-pin TSOP II with 0.8-mm pitch, are TTL-compatible, and dissipate 1W. $125, $110, and $100 (10,000). **Sony Electronics Inc**, San Jose, CA. (800) 288-7669. **Circle No. 377**

32- and 64-bit multimedia accelerators for graphics and video. The Trio32 ($20 (10,000)) and Trio64 ($30 (10,000)) are 32- and 64-bit, DRAM-based graphics accelerators with an integrated 24-bit RAMDAC. The accelerators provide 135-MHz-output pixel data rates. The company is also introducing Vision64-family 64-bit graphics engines, which offer pixel data bandwidths of up to 400 Mbytes/sec. The first member of the family, Vision866 ($35 (5000)) provides graphics acceleration. Vision868 ($42 (5000)) also integrates a video-playback engine. Vision968 ($60 (1000)) provides the features of the Vision868 but is VRAM-based. **S3 Inc**, Santa Clara, CA. (408) 980-5400.
Circle No. 378

Low-power CMOS device implements ANSI Open Fiber Control requirement. The S2036 is designed for eye-safety purposes. The part detects when the optical link has been disrupted in any way and instantaneously turns off the laser. The device meets the Class 1 safety limits defined by the FDA, ANSI, and IEC. The device operates at data rates of 1062.5, 531.25, and 265.625 Mbps. In a 28-pin SOIC, $6 (5000). **Applied Micro Circuits Corp**, San Diego, CA. (619) 450-9333. **Circle No. 379**

Submicron-linear-semiconductor process targets multimedia and data-communications designs. The 0.8-µm CWL linear CMOS process is identical to the company's AMI8Gx and AMI8S gate-array and standard-cell families, with the addition of a second polysilicon layer to accommodate linear capacitors. All of the company's 0.8-µm digital libraries, megacells, and memory compilers are available in the new process. The propagation delay for a two-input NAND gate is 230 psec. **American Microsystems Inc**, Pocatello, ID. (208) 233-4690. **Circle No. 380**

Media-access controller supports proposed IEEE 802.12 100VG-AnyLAN specification. The ATT-2M01 100VG-AnyLAN media-access controller is the latest member of the company's Regatta 100 LAN chip set. Main applications for the chip include implementing bus interfaces other than EISA or ISA, providing a network-management interface when the network-management interface is incorporated in the hub, and development of 10/100 frame-switching hubs that support both IEEE 802.3 and 802.12 protocols. ATT2M01 costs $19.20 (25,000). **AT&T Microelectronics**, Allentown, PA. (800) 372-2447.
Circle No. 381

MOSFET driver IC provides special features. The TK75050 is a noninverting buffer for driving high-power insulated-gate transistors. Special features include thermal protection, cycle-by-cycle current limiting, undervoltage lockout, and first-pulse wake-up, without requiring external circuitry. The device achieves 20-nsec rise and fall times when driving loads of up to 1000 pF. According to the company, high-speed cycle-by-cycle current limiting virtually eliminates the short-circuit runaway problem associated with most current-controlled converters. The first-pulse wake-up feature lets the circuit remain in a 800-µA sleep mode until the first drive pulse arrives at the input. When the supply voltage drops below the undervoltage-lockout threshold, the IC returns to sleep mode. $1.23 (1000). **Toko America Inc**, Mount Prospect, IL. (708) 297-0070. **Circle No. 382**

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Evaluation board for MPC505 PowerPC embedded microcontroller. The MPC505EVB provides a platform to aid in the creation, development, and debugging of 32-bit MPC505 application code. The evaluation board is the hardware portion of the company's complete MPC500 development environment. The board includes the MPC505, 512 kbytes of flash memory for program storage, 128 kbytes of burstable synchronous SRAM, debug monitor software, 68HC11 debugging-port interface control, an RS-232C port, dual UARTs, timer functions, two 96-pin connectors for expansion-board circuitry, interface connectors to bus analyzers, seven 20-pin connectors for a logic analyzer, two additional RS-232C ports, and SCSI-port provisions. $975. **Motorola Microcontroller Technologies Group**, Austin, TX. (512) 891-3260.
Circle No. 324

Serial-port card for PC/104 has four channels. The 4I23 provides four channels on a stackable PC/104 bus card. The card comes in three versions: quad RS-232C, quad RS-422, and two of each. The card uses 16C550-type UARTs with 16-byte receive and transmit FIFO buffers to minimize interrupt overhead and accommodate long interrupt latency. $149 (100). **Mesa Electronics**, Emeryville, CA. (510) 547-0837. **Circle No. 325**

Real-time environment for native signal processing on Pentium-based PCs. The IA-SPOX is a real-time kernel and development environment for the Intel Pentium. According to the company, the tool brings native signal processing to Pentium-based PCs, making it possible to run real-time multimedia tasks directly on the Pentium processor instead of using a separate DSP. Bundled with the software is WinSPOX, a tool based on the Microsoft resource-manager interface that provides an end-to-end, hardware-independent connection between Windows applications and SPOX real-time tasks. You can execute these real-time tasks on the Pentium or on an independent DSP. The product will be available in the first quarter of 1995 from $995. **Spectron Microsystems**, Santa Barbara, CA. (805) 968-5100.
Circle No. 326

PC/104 Sound Blaster-compatible audio module. The PCM-Audio PC/104 module can record, compress, store, and play back voice, sound, and music. The module is based on an ASIC containing an embedded μP, 12-bit A/D and D/A converters, DMA control with a FIFO buffer, memory, a timer, and a PC/104 logic interface. Audio utilities support operation in Windows, DOS, and non-DOS applications. The card requires 5V at 30 mA and operates from –40 to +85°C. $250. A development kit, including the module, two speakers, a microphone, a PC bus Sound Blaster-compatible board, and software, costs $595. **WinSystems Inc**, Arlington, TX. (817) 274-7553. **Circle No. 327**

Real-time interprocess communication link for Windows. The LT-Speedway high-speed interprocess link is now in the public domain. The object-oriented link has high throughput, and data has a guaranteed arrival time. The code is available free and is on-line downloadable from two sources. The files LTSPEEDW.ZIP and LTSPPEW.TAR.Z are available by anonymous ftp (file transfer protocol) from the /vendor/labtech directory at the ftp.uu.net site. The same files are in the Labtech forum library (type GO LABTECH) on CompuServe. Application developers requiring in-depth support can purchase the LT-Speedway developers kit, including documentation, examples, and regular code updates, for $1995. **Laboratory Technology Corp**, Wilmington, MA. (508) 657-5400.
Circle No. 328

Software-development platform for the TMS-320C31 floating-point DSP. The DSP-C31 development platform includes the TMS320C31 development system with an assembler, a symbolic debugger, and target hardware. The development platform includes all the tools necessary to develop, debug, and run DSP applications. The PC plug-in card provides a TMS320C31 IC, static memory, an analog I/O port, and two PC interfaces: a debugger interface and a high-speed data-transfer interface. The analog I/O port provides 14-bit A/D and D/A resolution and sample rates up to 19,200 samples/sec. The port also has built-in antialiasing and smoothing filters. $600. **Domain Technologies Inc**, Plano, TX. (214) 985-7593.
Circle No. 329

MPEG software-developer's kit for digital-audio, -video, and communication MPEG and ISDN boards. The software-developer's kit (SDK) serves users of the company's MPEG-compression and ISDN/T1 communication boards. The software aids in developing audio and video applications and distribution over LANs and WANs (wide-area networks). The SDK provides the means for creating applications to exchange compressed MPEG files over Ethernet, T1, or ISDN telephone lines. The SDK is compatible with the Open MPEG decode API and provides a set of DOS libraries, Windows drivers, and sample application code needed to create digital-audio and -video distribution networks. Annual subscription, $2500. **FutureTel Inc**, Sunnyvale, CA. (408) 522-1400. **Circle No. 330**

Floating-point routines for Fujitsu's RISC embedded processor family. The SCP32 set of floating-point routines suits designers who need floating-point functions without hardware constraints. According to the company, the product performs the typically slower, more complex operations of logarithms, exponentials, roots, and power up to 10× faster than conventional fast floating-point software. From $2500 with additional charges for trigonometric and hyperbolic function libraries. **Log Point Technologies Inc**, Mountain View, CA. (415) 967-3974.
Circle No. 331

Intel Pentium support package for Biomation logic analyzer. The μP Analysis Package (MAP) captures μP activity and displays disassembly in standard mnemonics or as timing diagrams and state listings. The product operates with the Biomation Configurable Logic Analysis System and accommodates instruction-access bus rates down to 10 nsec. The tool supports the Pentium 510/60, 567/66, 735/90, and 815/100 μPs. $4500. **Embedded Performance Inc**, Milpitas, CA. (408) 434-2210. **Circle No. 332**

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Custom graphic controls for developing data acquisition and test systems in Visual Basic. VisuaLab Version 2.0 offers 100 point-and-click tools and 50 controls. Data-aware input controls let an application retrieve previously acquired data from a database, graphical dial controls aid in application-process control, and other controls provide expanded data-analysis capabilities, such as advanced mathematical, statistical, and analytical functions. The software includes 221 pieces of clip art that help you customize the appearance of the controls. $395. **IOtech Inc**, Cleveland, OH. (216) 439-4091.
Circle No. 341

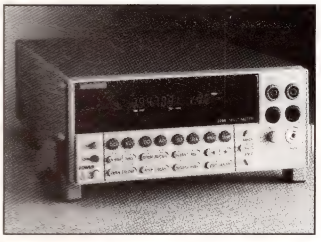
Experimental data-fitting software runs under Windows. The Scientist for Windows simulation and experimental data-fitting tool lets you fit simple equations. It also lets you fit combinations or systems of nonlinear algebraic equations, differential equations, and Laplace transforms. $295. **MicroMath Scientific Software**, Salt Lake City, UT. (801) 943-0290.
Circle No. 342

Logic analyzer offers 34 channels of 250-MHz timing or 50-MHz state for $4500. The HP 1664A logic analyzer offers 34 or 17 channels with 250- or 500-MHz timing analysis, respectively. The 34-channel mode also offers 50-MHz state analysis. For examining signals with infrequent activity over a longer period, the instrument provides 125-MHz transitional timing on 34 channels or 250-MHz transitional timing on 17 channels. A library of trigger macros, accessible through a graphical user interface, simplifies complex triggering setups. The system includes a mouse and an optional keyboard. **Hewlett-Packard Co**, Santa Clara, CA. (800) 452-4844, ext 8590.
Circle No. 343

Logic analyzer fits in pod and communicates over standard serial port. The Pod-A-Lyzer 8020 has 18 channels with a 64k-word trace buffer and captures data at 100M samples/sec. The logic analyzer connects to a serial port on a 386 or 486 PC running Windows. The palm- sized logic analyzer weighs <1 lb and requires 5V at 650 mA max. Other specifications include an 80-MHz synchronous clock speed, a 2.1-nsec setup time, zero hold time, TTL and CMOS thresholds, and a 100-kΩ, 10-pF input impedance. $1295. **Boulder Creek Engineering**, Boulder Creek, CA. (408) 338-3907.
Circle No. 344

Two- and four-channel digital storage oscilloscopes offer 20- to 100-MHz bandwidth. The ET-DSO boards plug into a PC ISA bus or install in a portable tabletop system and connect to a PC via the parallel LPT port. Each DSO channel has an independent 25M- or 40M-sample/sec, 8-bit A/D converter. The DSO has a 32k-word memory and provides 10 vertical-gain settings. Random interleave sampling provides pretrigger and post-trigger data. The two-channel, 20-MHz ET-DSO20-25A costs $695, and the two-channel, 100-MHz ET-DSO100-40A costs $1195. **Emulation Technology Inc**, Santa Clara, CA. (408) 982-0660.
Circle No. 345

PC-based spectrum analyzer covers 100-kHz to 2.4-GHz frequency. The SA2600 spectrum analyzer/receiver uses direct digital synthesis with a crystal reference to provide >2-Hz resolution. Video bandwidth is programmable from 300 kHz, and resolution bandwidth is programmable from 500 Hz. The instrument has a spurious-free dynamic range of 80 dB. An optional internal programmable 60-dB step attenuator lets the unit measure signals from –130 to +20 dBm. Internal gain compensation and power calibration provide power measurements accurate to ±1.4 dB. Wide and narrow FM demodulators provide audio for directed-search surveillance applications. The analyzer is available in PC internal and external configurations from $4995. **DKD Instruments**, Simi Valley, CA. (805) 581-5771.
Circle No. 346



6½-digit DMM performs 50 readings/sec. The Model 2000 DMM has 13 functions, including dc voltage; dc; ac voltage; ac; two- and four-wire resistance; continuity; diode test; frequency; period; decibel; decibel referred to 1 mW; and temperature support for J-, K-, and T-type thermocouples. An option slot in the back panel accepts a 10-channel scanner card. The unit also has IEEE-488 and RS-232C interfaces. $995. **Keithley Instruments Inc**, Cleveland, OH. (216) 248-0400.
Circle No 347

Spreadsheet-style unit-conversion program for Apple Macintosh. The Equalizer performs up to 261 conversions at once on nine units and lets you save and print the tables. The software contains >1500 units of the standard international, American, British, and metric system, along with assorted archaic and specialized measurements. $49.95. **Bare Hill Software**, Canandalgua, NY. (716) 554-5440.
Circle No. 348

Graphical instrumentation software adds features. LabView version 3.1 includes on-line help, configuration-management tools that aid in creating larger applications, and a call-library-function object that links Microsoft Windows dynamic-link libraries or Sun shared libraries. An application builder lets you create applications as single executables or as runtime systems and lets you distribute the applications royalty-free, provided they meet minimum licensing requirements. This release also includes a virtual-instrument-software-architecture library as a transition for instrument-driver developers and users. This library will become standard in future releases of the software. The software costs $1995 for Windows and Macintosh, $3995 for Sun, and $2995 for HP-UX systems. **National Instruments**, Austin, TX. (512) 794-0100.
Circle No. 349

Test-development software adds features. The TDS test-development series 7.0 and 7.1 offers features that improve timing specifications, stimulus-database representation, and stimulus conversion for testing ICs. The tools support the flow of specification-based timing equations from design to test. They also provide compression to increase storage efficiency for large test databases. New algorithms automate the conversion of simulation and test vectors to speed test-pattern preparation. The software starts at $59,000. An equation bridge option for Schlumberger and Teradyne testers costs $35,000. **Summit Design Inc**, Beaverton, CA. (503) 643-9281.
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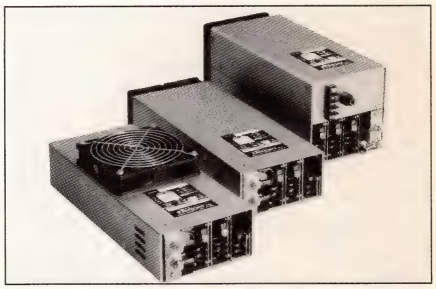
3A switching-regulator SIPs suit BTL/Futurebus+, CTT-bus, and GTL-bus applications. The integrated switching regulators convert 5V dc to 1.8V dc (PT6306), 2.1V dc (PT6307), and 1.2V dc (PT6308). The 12-in. devices are 0.36×2×0.6 in. high, operate at 650 kHz, and provide up to 77% efficiency. The regulators have an adjustable-output voltage and feature internal short-circuit and over-temperature protection. The devices require one external capacitor. $19.90 (100). **Power Trends Inc**, Batavia, IL. (708) 406-0900. **Circle No. 384**

20W dc/dc converter family offers 2:1 input-voltage range. The 2100 series dc/dc converter family is available in 24 models accepting 9 to 18, 18 to 36, and 36 to 72V. Single, dual, and triple outputs provide +5, +12, +15, ±5, ±12, or ±15V dc. The 2×2×0.375-in. modules offer 500V-dc input-to-output isolation, continuous short-circuit protection, output-overvoltage protection, and efficiencies to 87%. Output-voltage accuracy is ±1%, and line/load regulation is ±0.5%. All models include remote on/off control. Prices range from $90.30 (100) for single-output models to $104.30 (100) for triple-output models. **Conversion Devices Inc**, Brockton, MA. (508) 559-0880. **Circle No. 385**

600W ac/dc converter has power-factor correction. The Model PFC-600 UniVerter accepts an 85V- to a 265V-ac input and converts it to 380V dc for powering the company's μV300 Series of dc/dc converters. The PFC-600 provides power-factor correction to meet the low-harmonic-distortion requirement of IEC555-2. The module provides a power-fail warning when the output drops below 355V dc. The device comes in a package measuring 0.5×2.4×4.6 in and is 90% efficient for 120V-ac input and 94% efficient for 240V-ac input. $150 (100). **RO Associates Inc**, Sunnyvale, CA. (408) 744-1450. **Circle No. 386**

Power-factor-corrected 1000W supply meets IEC555-2 requirements. The PM3386B supply has a >0.99 power-factor correction. The supply provides one to five adjustable 2V- to 24V-dc outputs with current capacities to meet custom requirements. You can use the 5×5×11-in. supply in N+1 fault-tolerant systems, and a hot-pluggable version is available. Standard features include remote voltage sensing and overcurrent, short-circuit, overvoltage, and reverse-voltage protection. Input-voltage range is 96 to 264V ac. Holdup time in case of a power failure is at least 25 msec. From $1095. **Pioneer Magnetics**, Santa Monica, CA. (310) 829-6751. **Circle No. 387**



Output-module option for switching power-supply family. The Moduflex FM series switching-power supplies offer an optional enhanced output module. Features include a star-point current-sharing configuration for parallel or N+1 redundant operation, remote sense and inhibit for each output, margining, dc output, good logic signal with LED visual indicator, a 5V-dc bias source on auxiliary outputs, and VXI/VME power-fail monitor on the main output, providing both ACFAIL and SYSRESET signals. Each output has individual rectangular current limits that automatically recover when the overload is removed. The supplies offer 0.99 power-factor correction and are available with one to seven outputs, 600 to 2000W. A typical 600W supply with the enhanced output module costs <$1per watt (OEM quantity). **Deltron Inc**, North Wales, PA. (215) 699-9261. **Circle No. 388**

DC/DC converter provides up to 5000V. The K50 dc/dc converter has an input of 22 to 30V and an output of 0 to 5000V at 0.6 mA. The 3×3×0.89-in. module has 0.2% ripple-and-load regulation and suits use in capacitor charging, ionization chambers, photomultipliers, Geiger counters, vidicon tubes, spectrometers, CRT anode/focus, image intensifiers, and laboratories. Other voltage ranges are available. $139. **EMCO High Voltage Supply Co**, Sutter Creek, CA. (209) 223-3626. **Circle No. 389**

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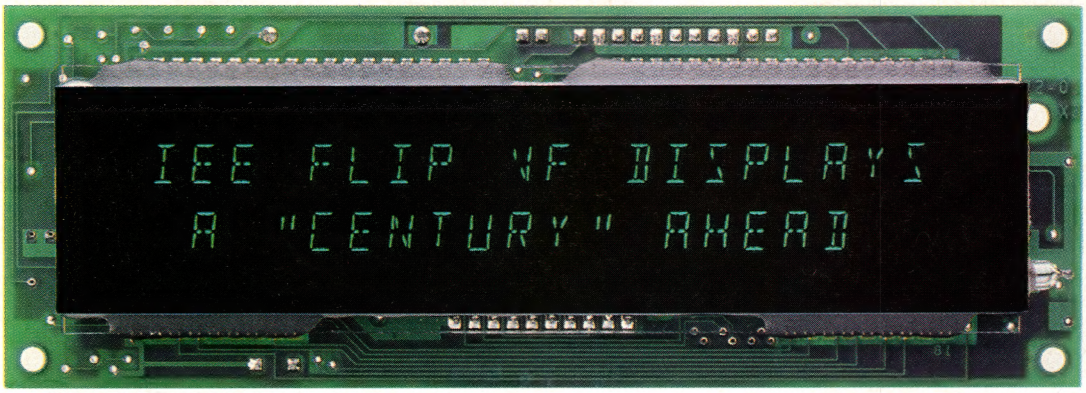

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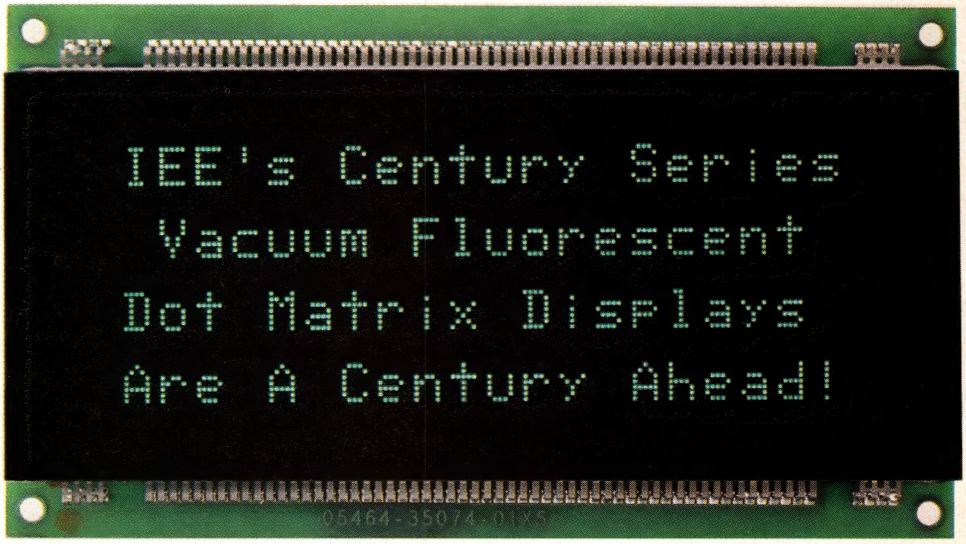

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03602-105-05220	5x7 dot matrix	2x20	5mm	5.00″	2.25″	0.88″	405mA
03602-122-09220	5x7 dot matrix	2x20	9mm	7.75″	2.58″	1.00″	675mA
03602-124-09420	5x7 dot matrix	4x20	9mm	7.75″	3.40″	1.00″	1300mA
03702-020-05220	14-segment	2x20	5mm	5.65″	1.98″	0.82″	270mA
03702-021-08110	14-segment	1x10	8mm	5.00″	1.60″	0.90″	140mA
03702-022-13112	14-segment	1x12	13mm	7.20″	2.40″	0.90″	323mA
03702-024-09116	14-segment	1x16	9mm	6.70″	2.30″	0.90″	360mA
03702-026-09120	14-segment	1x20	9mm	8.30″	2.35″	0.95″	390mA
03702-029-13120	14-segment	1x20	13mm	10.20″	1.93″	0.96″	526mA

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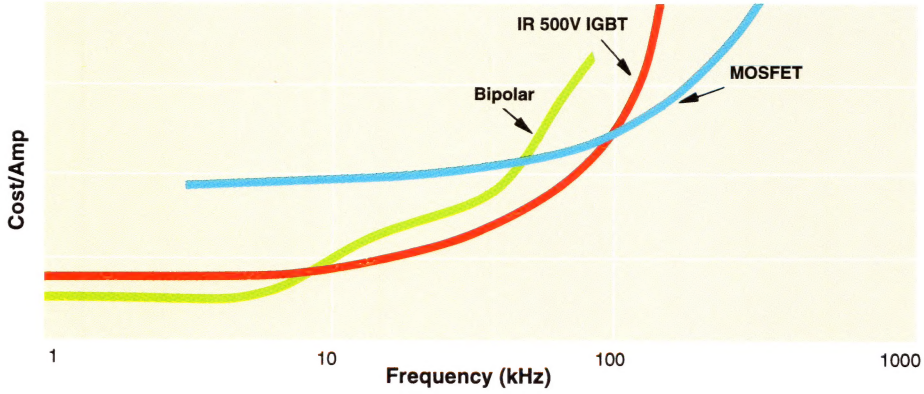

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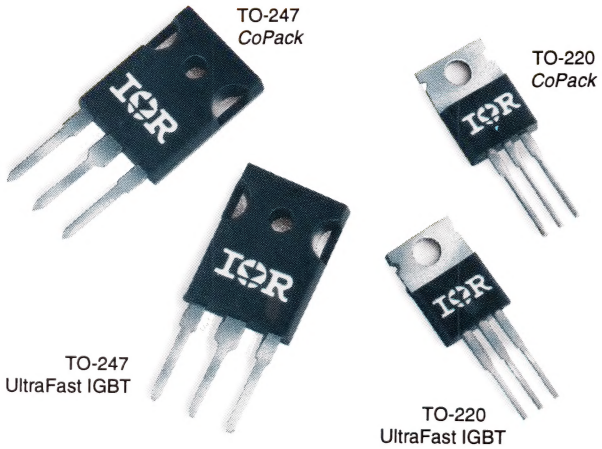

Available now at key IR distributors.

International Rectifier

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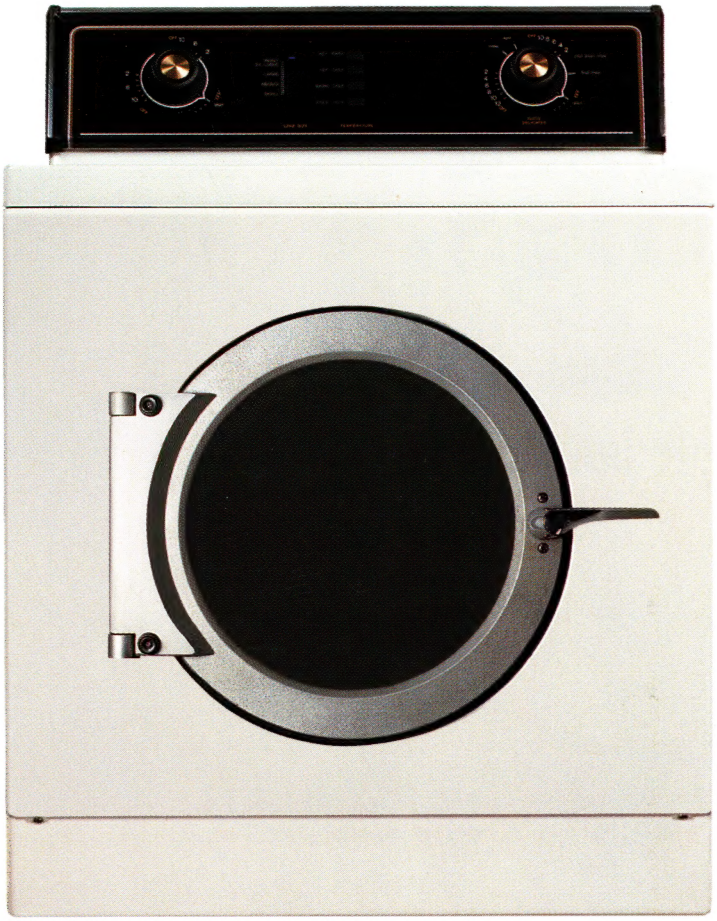


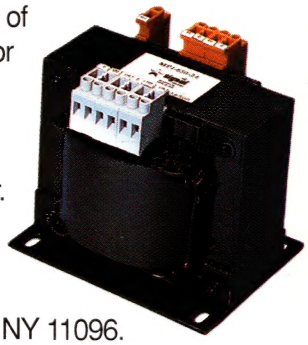
You'll love the fit of our new pre-shrunk transformers.

We shrunk the size and weight of our Multi-Purpose and High-Power International transformers up to 30% to provide greater performance in less space.

In applications the world over, Signal's high-power transformers are setting the standard in performance, reliability, and space efficiency.

Each one meets international standards including UL, CSA, VDE, IEC and EN.

They have high isolation of 4000 VRMS, low leakage for medical requirements, and shielding that reduces common-mode noise. Regulation is 7.5% or better.



For a full-line catalog, contact Signal Transformer, Insilco Technologies Group 500 Bayview Ave., Inwood, NY 11096.

General Specifications, MPI and HPI Series:

- **Power:** 200 VA to 3500 VA
- **Low Leakage Current for medical applications**
- **5 mils thick copper Faraday shield reduces common mode noise**
- **Shield terminated to handle high currents**
- **MPI's:** Incorporate Faston/screw type shock proof terminals
- **HPI's:** Incorporate EURO style screw terminals
- **MPI's:** Operate at: 100V, 115V, 200V, 215V, 230V–50/60Hz
- **HPI's:** Operate at: 100V, 115V, 215V, 230V–50/60Hz
- **MPI's:** Approvals: UL recognized to UL 506 (File #E63829)
  CSA certified to C22.2 #66 (File #LR51265)
  Designed to meet VDE 0805, VDE 0550 and IEC 950
- **HPI's:** Approvals: UL recognized to UL 506 (File #E63829)
  CSA certified to C22.2 #66 (File #LR51265)
  VDE certified to VDE 0550 (File #2994)
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Custom versions also available

Multi-Purpose International (MPI) Series

VA (Size)	L	W	H	WGT
200	3.750″ 95.3mm	4.203″ 106.6mm	3.720″ 94.5mm	6.22 lbs 2.82 kg
250	4.125″ 104.8mm	3.898″ 99.0mm	4.000″ 101.6mm	6.76 lbs 3.07 kg
300	4.125″ 104.8mm	4.223″ 107.3mm	4.000″ 101.6mm	7.80 lbs 3.54 kg
400	4.125″ 104.8mm	4.805″ 122.0mm	4.000″ 101.6mm	9.82 lbs 4.46 kg
650	5.250″ 133.3mm	4.430″ 112.5mm	4.800″ 121.9mm	14.83 lbs 6.73 kg
900	5.250″ 133.3mm	5.197″ 132.0mm	4.800″ 121.9mm	19.84 lbs 9.01 kg

Output voltages available from 5V to 230V

High Power International (HPI) Series

VA (Size)	L	W	H	WGT
2000	7.50″ 190.5mm	5.60″ 142.2mm	6.56″ 166.6mm	41.3 lbs 18.71 kg
2700	7.50″ 190.5mm	6.23″ 158.2mm	6.56″ 166.6mm	48.0 lbs 21.77 kg
3500	7.50″ 190.5mm	7.33″ 186.2mm	6.56″ 166.6mm	62.4 lbs 28.30 kg

Output voltages: Series–230V, Parallel–115V

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